Pattern perception and temporality in the music of Steve Reich: an interdisciplinary approach

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Pattern Perception and Temporality in the Music of Steve Reich: An Interdisciplinary Approach

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Stephanie Wilson

Abstract

This dissertation examines pattern perception and temporality in the music of Steve Reich. The research was based on the thesis that the temporal experience of Reich's music is significantly influenced by how a listener's perceptual ordering faculties respond to the ambiguous pattern structures which characterise much of his work.

The study had two primary aims. The first was to evaluate the potential for research in auditory perception to provide insights into the temporal nature of Reich's music. The second aim was to investigate how resulting patterns participate in the perception and cognition of his music. The interdisciplinary approach adopted in this research responds to the lack of information on Reich's music, and a prevailing view among musicologists that his compositions resist conventional analysis.

The analysis conducted in this thesis was divided into two parts. The first involved a beat class analysis of Reich's phase shifting music to consider evidence for internal progressive structures which imply goal-direction. The second part involved the design and implementation of a series of experiments which tested the salience of resulting patterns, and listeners' perception of pulse in Reich's *Piano Phase*. Together, the different analytical perspectives presented in this study contribute to a more complete understanding of the temporal nature of Reich's music.

While a principal aim of this study was to contribute to a better understanding of Reich's music, the research simultaneously confronted a range of methodological issues associated with conducting interdisciplinary research. That is, this study assessed the capacity for certain theories in auditory perception to shed light on the perception of authentic examples drawn from the Western musical repertoire. The results suggested that current models of pulse perception have the potential to predict aspects of pulse salience in relatively complex stimuli, such as the music investigated in this study. Similarly, findings suggested that the principles of auditory stream segregation can be used to contribute to an understanding of music which exploits perceptual thresholds and ambiguous musical relationships. In this way the study

provides a model for future research which seeks to examine the interaction between linear and nonlinear characteristics of musical time.

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Chapter 1

Nature and Scope of the Study

Introduction

> True understanding of the perception of musical time cannot come from psychology or [music] theory alone. Perhaps it can come from a marriage of these two imperfect disciplines. (Kramer, 1988, p. 324)

While the role of perceptual grouping processes in vision has had a relatively long research history, there is very little material prior to 1965 which deals with the perceptual questions of audition. Due to its comparatively short history, research on *auditory scene analysis* necessarily focuses on simple sequences of tones, in order to inform an understanding of how listeners might respond to relatively simple sound events when they are combined in various ways. Consequently, understanding the role of perceptual grouping processes in actual music, as opposed to auditory sequences created in the laboratory, is a far more complex endeavour. While the aims of auditory perception research are commonly considered incompatible with the aims of musicology, I suggest that recent trends in contemporary music might provide an avenue for a more successful relationship between the two disciplines. Specifically, I refer to the changing role of temporality in some recent music.

Composers in the twentieth century have used many different techniques to challenge conventional notions of musical time. Many have abandoned traditional linear musical structures in favour of nonlinear systems of organisation. Nonlinear systems of music de-emphasise the relationship between successive events over time, focusing more on the details of surface structure and/or relationships within small isolated structural units. Accordingly, a knowledge of the way sounds segregate and cohere under different conditions has the potential to inform an understanding of certain types of nonlinear music.

A primary concern for music theorists is that studies of music perception often report findings which are already understood intuitively by musicians and composers. This concern is accentuated by the fact that music perception research often focuses on examples from the Western music repertoire which have been rigorously examined by music theorists over many years. In fact, practically all studies of music perception utilise historical tonal music of the eighteenth century. Music perception studies have not dealt with twentieth century music, perhaps because it frequently challenges traditional musical analysis.

The analysis presented in this thesis, both musicological and perceptual, focuses on Steve Reich's early instrumental phase shifting works for reasons explained in the limitations section of this chapter. These works include *Piano Phase* (1967), *Violin Phase* (1967) and *Phase Patterns* (1971). The results of the analysis are used to inform a discussion of several of Reich's later compositions. These works include *Four Organs* (1970), *Drumming* (1970-1), *Music for Mallet Instruments, Voices and Organ* (1973), *Six Pianos* (1973), *Tehillim* (1981), *The Desert Music* (1984) and *The Four Sections* (1987). This research responds to the lack of critical information on Reich's music, and minimalism in general, by formulating an approach which integrates research from music theory and auditory perception.

A significant concern for music theorists regarding music perception research involves the use of 'non-musical' stimuli in experimentation. Musicologists argue that the results of perception experiments cannot possibly account for the complexity of the musical experience, which is based on intricate relationships between simultaneous musical parameters. For example,

> ... while psychologists of music have produced impressive lists of experiments, write-ups and results, what they have actually tested is, in the main part, too trivial to justify the elaborate experimental apparatus... they have mostly failed to use either actual music of any size or complexity, or, musically speaking, non-trivial material...(Barry, 1990, p. 11).

Similarly, many experiments in music perception isolate a single musical dimension, such as pitch, without considering how it functions when paired with rhythm, timbre, dynamics, and other elements which combine to form the expressive qualities of music. The rigorous methodology necessary to conduct psychological experiments often distorts the musical context. By extracting brief fragments of music from their temporal framework, the relationship between the temporal microstructure and macrostructure is lost. In this sense, the musical excerpts "may become totally cerebralized and alienated from music as experience" (Barry, 1990, p. 12). This issue is particularly problematic with regard to the study of 'linear' styles of music, in which the relationship between successive events and sections is fundamental to the overall temporal experience.

As will be demonstrated however, Reich's phase shifting music is not based on 'traditional' linear structures. Instead, much of the listening activity occurs between simultaneous layers of sound. I argue that music based on the repetition of small motifs, which seeks to avoid progressive relationships, is less corrupted in perception experiments, because these motifs can be examined in relative isolation. While I argue that the consistency of repetition over time is central to the temporal experience of Reich's music, the focus on the 'perceptual present' (to be argued in Chapter 2) minimises the problems associated with 'displacement' which are common to music perception experiments.

Clarke (1989) suggests that musicology and the psychology of music "remain distinct in terms of their aims and hence their evaluation of different findings" (p. 1). For example, the aim of the composer and musicologist in relation to issues of musical structure is "to formulate theories of the structural relations within and between musical works, and their origins, development and effectiveness as formal devices" (p. 2). By contrast, the aim of the psychologist is "the development of the theories of the mental processing of musical events, or the relationship between the listener, performer or composer and the musical environment" (p. 2). However, when we consider that progressive structural relations in Reich's early works are kept to a minimum, the aim of the musicologist becomes more like that of the psychologist. This is because the mode of listening, and listening processes, determine which patterns are heard, and how the listener responds to the ambiguous musical texture. In support of Kramer's (1988) view, which prefaces this chapter, I believe that a veritable understanding of the perception of musical time may come from a combination of music theory and psychology.

Previous analyses of Reich's music, conducted within the discipline of music theory, are limited and often restricted to description. Several researchers have argued that Reich's music is unsuitable for analysis due to the absence of structural reference points, and its 'timeless' quality. I suggest that the limited number of analyses on Reich's music in the literature stems from the fact that formal musicological analysis is challenged by the nonlinear characteristics of his music.

In response to this problem, the approach to pattern perception and temporality in Reich's music is an interdisciplinary one in this research. It utilises research from both music theory and auditory perception to explore how pattern participates in the perception and experience of Reich's music. This study is concerned with how listeners might extract patterns from the musical texture. The perceived patterns in Reich's instrumental phase shifting compositions are referred to throughout this thesis as 'resulting patterns'. In order to establish how resulting patterns are formed in Reich's music, I explore perceptual grouping processes in accord with principles derived from auditory scene analysis, and other related research on melodic and rhythmic perception.

Purpose of the Study

As a means of better understanding the music of Steve Reich, I propose that the temporal experience of his music is significantly influenced by how a listener's perceptual ordering faculties respond to the ambiguous pattern structures which characterise much of his work. In order to examine this thesis, two central questions were investigated:

1. How does pattern influence the perception and cognition of Reich's phase shifting music?

2. How can perception research contribute to an understanding of temporality in Reich's music?

In answering Question 1, two issues were addressed. The first concerns inherent musical structures, and the second concerns perceived structures:

(a) What evidence is there for linear structures in a musicological analysis of Reich's phase shifting music?
(b) What perceptual processes are responsible for the formation of patterns in Reich's music, and how do they influence the listener's experience of time?

In order to answer Question 2, the following issues were investigated:

(a) What experimental methodologies are suitable for an investigation of pattern perception in Reich's music?
(b) How does an investigation of pattern perception in Reich's music inform an understanding of his compositional development, and affinity with the minimalist style?

While the primary aim of this research is to contribute to literature on Reich's music, the research simultaneously tests the application of certain theories in auditory perception, and their ability to shed light on the perception of more complex music.

Plan of Methodology

In the first phase of study, a literature review was conducted to assess existing commentary on, and analyses of, Reich's music. This survey exposed a significantly limited body of research. Prominent in the literature however, was the suggestion that the 'timeless' nature of Reich's music made it unsuitable for conventional musical analysis, with the result that the bulk of literature on the subject is restricted to description.

The approach to temporality in Reich's music, adopted in this research, is guided by studies of musical time, in particular Jonathan Kramer's *The Time of Music* (1988) and Barbara Barry's *Musical Time: The Sense of Order* (1990). Both emphasise the need to approach the issue of musical time from several different perspectives. For example, Kramer suggests that studies of musical time:

> ... must be willing to adopt a variety of different assumptions, and must utilize many methodologies: scientific vs. humanistic, objective vs. subjective, value-free vs. evaluative, relativist vs. universalist, speculative vs. verifiable. (Kramer, 1988, p. 2)

Similarly, Barry states:

> ... no description of musical time would be anywhere near complete if it included only the objective observation of musical data. What is essential and complementary to this is an account of how music is perceived as temporal process which will, in turn, require identifying key factors in the phenomenon of musical time. If musical time can be described as the interaction between two distinct components, one being the innate organization of the work - its style, harmonic characteristics, internal subdivisions and so on - then the other is the respective part played by the individual in the perception of time. (Barry, 1990, p. 12)

Consequently, the first phase of the study involved the formulation of a conceptual framework which can be used to explore different perspectives of time in Reich's music. A principal aim was to consider the philosophic and musical factors which influence how time is felt to pass (Chapter 2).

The second phase of the study (Chapter 4) involved an analysis of three of Reich's instrumental phase shifting works: *Piano Phase* (1967), *Violin Phase* (1967) and *Phase Patterns* (1970). In accord with the research questions proposed, the analysis considered evidence for linear structures in the music, and the extent to which these structures influence the listener's experience of time. Following a method adopted by Richard Cohn (1992), the analysis focused on the *beat-class sets* which arise from the principal patterns of each composition when run through the phase shifting process.

In the third phase of the study, a literature review was conducted on the process of *auditory stream segregation* as a basis for its exploration in the context of Reich's music. The inquiry was based on the understanding that stream segregation is the process responsible for the segregation of a repeating pattern into two or more individual pitch streams. The information in this review was used to generate hypotheses for two experiments which sought to test the salience of resulting patterns in Reich's *Piano Phase*. The survey was directed by three aims: 1) to consider what musical features influence the segregation of patterns; 2) to examine the different types of methodologies which have been used to measure stream segregation; and 3) to assess whether or not these methodologies were suitable for an investigation of pattern perception in Reich's music.

The fourth phase of study involved the design and implementation of two experiments (Experiments 1A and 1B) which explored the perception of pulse in Reich's phase shifting music, specifically, the ambiguity of the downbeat (Chapter 5). A second literature survey was conducted on models of pulse and meter perception, to generate several hypotheses for Experiment 1A and 1B. Prior to the experiments, two pilot studies were conducted to test certain aspects of the experimental design and procedure. Experiment 1A collected listeners' pulse responses to a series of excerpts from Reich's *Piano Phase*. Using a similar procedure, Experiment 1B divided the stimulus patterns into individual pitch streams (resulting patterns) to consider which patterns in the music influenced listeners' perception of pulse. The next phase of study involved two further experiments (Experiments 2A and 2B) which were designed to test the perceptual salience of resulting patterns in Reich's *Piano Phase*. Participants were divided into musical and non-musical groups to assess the influence of musical experience (Western tonal and contemporary music) on the segregation of patterns.

In the final phase of study, the results of the different analyses conducted throughout the study were readdressed from the perspective of music theory (Chapter 7). For example, the results were used to demonstrate that certain features of Reich's phase shifting works remain strong temporal forces in his later compositions. In addition, the results are used to discuss the limitations of current definitions of minimalism, and to draw parallels between Reich's music and more recent compositional trends. The final chapter (Chapter 8) consists of a summary of the main findings of the study, followed by conclusions and recommendations.

This dissertation is exploratory in nature and reflects an evolving strategy. Such a path was necessary to investigate the potential contribution of perception research to an analysis of Reich's music. As a result, the thesis ventures into the areas of musicology, philosophy, music perception, auditory perception, psychoacoustics, and music psychology. Consequently, a glossary of terms has been included with the appendices. Terms that appear in the glossary are italicised the first time they appear in the text. Full scores of the phase shifting compositions are provided in Appendix B, so that they may be examined in parallel with the relevant sections of the text. The appendices (E, F, G and H) provide details of the computer programs designed to run the experiments conducted in this research.

Limitations of the Study

Due to the interdisciplinary issues raised above, and the exploratory nature of the research, several restrictions were made in this study.

Limitation 1: Experimental stimuli

While the theoretical evaluation of the role of stream segregation in Reich's music is discussed in relation to three of his instrumental phase shifting works (Chapter 4), the experimental investigation is restricted to *Piano Phase* (1967) (full score in Appendix B). There are several reasons for this restriction. The composition moves through a complete cycle of the phase shifting process, which means that the first six permutations of the principal pattern are identical to the last six in section A. Consequently, the principal pattern and the first six phases form the basis of the experimental stimuli (in Experiments 1 and 2). The length and complexity of *Violin Phase* and *Phase Patterns* made them less suitable for experimentation. The results of the experiments, however, form the basis of a series of assumptions which can be applied to the remaining phase shifting compositions. Similarly, while the experimental stimuli excludes the *acceleration regions* of the music, these regions are examined hypothetically according to the principles of stream segregation, allowing a discussion which could not be achieved via formal musical analysis.

Limitation 2: Pulse perception and stream segregation

The experimental component of the research (Chapters 5 and 6) focuses on two aspects of perception in Reich's music. The goal of the present study is to utilise research in perception to contribute to a meaningful understanding of the structure of Reich's compositions. For this reason, the experimental component of the research focuses on aspects of the music that the composer deems fundamental to the experience of these works (Reich, 1974). Specifically, these aspects include sudden perceptual shifts caused by rhythmic ambiguity in the music, and 'resulting patterns' or 'psychoacoustic by-products'. These resulting patterns form the melodic and rhythmic characteristics of the music perceived by the listener. In response, Experiments 1A and 1B consider the ambiguity of pulse perception in Reich's music, and Experiments 2A and 2B examine the salience of resulting patterns, and consequently, their contribution to the temporality of these works.

Limitation 3: Subject sample

The subject sample in the experiments reported in Chapters 5 and 6 consisted of Western listeners only. While the influence of culture on the salience of resulting patterns is a valid consideration, there has been no research to date which has tested cultural influences on stream segregation. While a cross-cultural comparative study of the perception of resulting patterns in Reich's music was conducted during the research period, the lack of existing research limited the interpretation of results. However, the experiment conducted raises a series of important questions which may be useful for future research. For this reason, the methodology and results of the study are reported in Appendix A.

As a preface to the present research, it is informative to provide an account of Reich's musical background, and to outline the relatively small body of literature devoted to the composer's music, and minimalism generally.

Background

Steve Reich was born in New York City in 1936. As a teenager, he studied drumming with Roland Kohloff who was, at the time, the principal timpanist with the New York Philharmonic Orchestra. In 1957, Reich graduated from Cornell University, receiving a Bachelor of Arts in Philosophy with honours. The subject of his thesis was the later works of Ludwig Wittgenstein (1889-1951), an Austrian linguistic philosopher who had visited the university several years earlier. In addition to philosophy, Reich studied music history with William Austin. Of particular interest to Reich during his time at Cornell University was the study of Gregorian chant, and the music of Bach, Debussy and Stravinsky.

After completing his B.A., Reich returned to New York, and studied composition with Hall Overton, a classical composer and jazz arranger. During this time, much of his training focused on the works of Bartók, and the textbooks of Hindemith.

> I got the arch form from Bartók. I got the idea of working with canons from Bartók's *Mikrokosmos*. I got the clarification of the modes from Bartók. And later, in the late '70s, by looking at the beginning of the second movement of his Second Piano Concerto, I found the resuscitation of parallel intervals, which Bartók may have got from Debussy's "Sunken Cathedral," particularly fourths and fifths, as if the Middle Ages were translated into the twentieth century. (Reich in Strickland, 1991, p. 37)

After studying with Hall Overton, Reich attended the Julliard School, where he studied with two American composers, William Bergsma and Vincent Persichetti. At Julliard, he was introduced to the works of the integral serialists, namely Boulez, Stockhausen and Berio. Reich's early interest in repetitive structures is clearly reflected in his approach to the composition of twelve-tone music at this time: "...the only way I could deal with it was not to transpose the row or invert the row or retrograde the row, but to *repeat* the row over and over and over again..." (Reich in Strickland, 1991, p. 39). Reich's study of composition continued at Mills College in Oakland, where he studied with Luciano Berio and Darius Milhaud, graduating in 1963 with an M.A.

Reich began his compositional career while rehearsing for the premiere of Terry Riley's composition *In C*. His first two compositions, *It's Gonna Rain* (1965) and *Come Out* (1966), utilise the technique of gradually phasing pre-recorded fragments of speech using tape loops. The phase shifting process, which Reich first explored using electronic devices, was later adapted for live musicians. For example, compositions such as *Piano Phase* (1967), *Violin Phase* (1967) and *Phase Patterns* (1971) are concerned specifically with the audibility of this gradual process. This early interest in the phase shifting process formed a lasting impression on the composer, and continued to play an influential role in many of his later compositions.

In 1970, Reich went to the University of Ghana in Accra to study drumming with Alfred Ladzepko, a master drummer of the Ewe tribe. His decision to go to Africa was based on his early introduction to African music by William Austin at Cornell University, and his later study of the transcriptions in A.M. Jones's *Studies in African Music* (1959). In reference to these transcriptions Reich states that he was interested in the "superimposition without coinciding downbeats of regular repeating patterns of varied lengths in what he notated as 12 / 8" (Reich in Strickland, 1991, p. 40). The use of repeated patterns and ambiguous downbeats is prominent in Reich's composition *Drumming* (1970-1), which was composed on his return from Africa. Reich describes his exposure to African music as a confirmation of his pre-existing ideas about musical structure, many of which were already in place in previous compositions (Reich, 1974).

The next phase of Reich's compositional career coincides with his study of Balinese gamelan music at the University of Washington in Seattle. This period of study is often viewed as having a strong influence on compositions such as *Music for Mallet Instruments, Voices and Organ* (1973), *Music for 18 Musicians* (1974-6), *Music for Large Ensemble* (1978) and *Octet* (1979), all of which involve "more complex counterpoint and timbral variety" (Strickland, p. 34). Interestingly, *Music for Mallet Instruments, Voices and Organ* (1973) was composed prior to this period of study. The influence of African and Balinese music on Reich's compositions therefore, is not as straightforward as critics often believe (Strickland, 1991). In Reich's own words:

> ...one can study the rhythmic structure of non-Western music and let that study lead one where it will while continuing to use instruments, scales and any other sounds one has grown up with. This brings about the interesting situation of the non-Western influence being there in the thinking, but not in the sound. (Reich, 1974, p. 40)

In 1976-7 Reich studied traditional Hebrew cantillation of the Scriptures. Although Reich was raised a Reform Jew, he had little knowledge of his cultural or religious tradition prior to this period. He states, "I had not heard Hebrew chant, I did not know the Hebrew language, I did not know the Torah was read in an annual cycle, I didn't know *anything*" (Strickland, 1991, p. 43). This resulted in his study of Hebrew, the Torah, and cantillation. In music, "cantillation involves a single line made up of varying smaller components strung together to make a much longer line" (Reich in Strickland, 1991, p. 44). While this technique is explicit in Reich's *Octet* (1979), it is not applied in *Tehillim* (1981), a composition based on the setting of a Hebrew text.

Reich has always been involved with the performance of his own music. In 1966, he formed a small ensemble, consisting of himself, pianist Art Murphy, and woodwind player Jon Gibson. In 1967, several additions were temporarily made to the ensemble, including pianist and composer James Tenney, to perform a four piano version of *Piano Phase*. Joining the ensemble in 1970, were Steve Chambers and occasionally Philip Glass, who were involved in playing *Phase Patterns*, and *Four Organs*, a composition requiring five musicians. When *Drumming* was completed in 1971, the number of performers expanded to twelve musicians and singers, and adopted the name *Steve Reich and Musicians*.

Reich's association with minimalists in the visual arts created several opportunities for the composer early in his career. For example, many of his early works were first performed in art galleries and artists lofts, rather than in the concert hall. Referring to a performance of *Piano Phase* in 1967, Reich states: "I felt at home with my painter friends, mostly listening to jazz, and through them I was offered a chance to do a concert of my music at the Park Place Gallery, *the* gallery of minimal art" (Reich in Strickland, 1991, p. 41). Similarly, a performance of Reich's composition *Pendulum Music* (1968), at the Whitney Museum in New York in 1969, included three minimalists from the visual arts among its performers (Bernard, 1993).

Literature

The literature on minimal music is not extensive. Wim Mertons' text, titled *American Minimal Music* (1983), is the only book-length examination of minimal music. Mertons surveys the music of Steve Reich, Philip Glass, La Monte Young, and Terry Riley, and discusses the context in which their music was performed and composed. A more recent publication is Edward Strickland's *Minimalism: Origins* (1993), which discusses minimalism as an artistic movement, in particular, its early development in music and the visual arts. Several texts on contemporary music provide very general insights into the characteristics of minimalist music. An exception is *Experimental Music: Cage and Beyond* (1974), by Michael Nyman, who provides a relatively detailed description of several early minimalist works. Glen Watkins, in his book *Soundings: Music in the Twentieth Century* (1988), draws attention to similarities between minimalist compositions, and earlier works which demonstrate a general reduction of musical materials, and contain similar surface qualities.

A number of other authors have written articles which explore the origins of minimal music. For example, Peter Gena (1981) examines the relationship between indeterminacy and minimalism, while Kyle Gann (1987) draws parallels with serialism. In opposition to Gann's article, Elaine Broad (1990) focuses on similarities between minimalism and experimental music, in particular, the fact that both types of music are concerned with *ateleology* (non-goal directed structures). A different approach is adopted by Robert Carl (1989), who examines the origins of minimalism and modernism, making links between the two in an attempt to interpret recent compositional trends. Timothy Johnson (1994) reviews current definitions of minimalism in music, and argues that definitions need to be expanded to accommodate more recent developments of the style.

One of the most valuable resources on the music of Steve Reich is the composer's own collection of essays. In this volume, titled *Writings About Music* (1974), Reich provides detailed explanations of his compositional techniques and processes. Other than this, there are only a small number of articles devoted to Reich's music. For example, Paul Epstein (1986) provides an analysis of *Piano Phase*, focusing on the structural characteristics of patterns as they move through the phase shifting process. Richard Cohn (1992) presents a comprehensive analysis of two of Reich's phase shifting compositions using set theoretic techniques.

In summary, the evolving strategy adopted in this study responds to the few connections between studies of music perception and musicological analysis, and the inadequacy of both musicological analysis and perception studies in dealing with much twentieth century music. Reich's music was considered an appropriate choice for demonstrating that important insights into musical time can be gained by strengthening the rapport between the disciplines of musicology and music perception. As outlined in the Plan of Methodology, the following chapter sets up a conceptual framework for exploring different perspectives of time in Reich's music, and considers the philosophic and musical factors which influence how time is felt to pass.

Chapter 2

Patterns, Percepts, and Perennials

Introduction

> In music I must feel a physical here and there and not only a now, which is to say, movement from and toward. I do not always feel this sense of movement or location in, say, Boulez's *Structures* or those fascinating score plans by Stockhausen ... and though every element in those pieces may be organized to engender motion, the result often seems to me like the essence of the static. A time series may well postulate a new parable about time, but that is not the same thing as a time experience, which for me is a dynamic passage through time. (Igor Stravinsky, 1982, p. 127)

Stravinsky's desire to hear "movement from and toward" describes an experience that is traditionally associated with Western music listening. When listening to music we recognise reference points and identify temporal markers which suggest that we have moved on, and that we have been transported from one 'place' to another. Stravinsky's use of the word "location" in music suggests an awareness of place, where the perceived location is defined by reference to the past, and anticipation of the future. It is this active participation in the movement of music that creates the sensation of "a dynamic passage through time".

So how does a piece of music, such as Boulez's *Structures*, that appears to be "organized to engender motion", result in a sense of apparent stasis? The notion of hidden structures in music draws our attention to the rift between inherent structures and perceived structures. It also makes us question the extent to which a knowledge of hidden structures closes the gap between the two. A notable contradiction arises when we consider that pieces of music built on processes intended to be perceived, such as Steve Reich's phase-shifting music, are also capable of invoking a sense of the perceptual present.

To address these issues, this chapter includes two complementary parts. An underlying theme of both involves an exploration of the relationship between pattern structure, perceived structure, and the phenomenon of musical stasis. Part One, section one, begins with a discussion of the various analytic platforms from which musical time may be observed and interpreted. In section two, I consider the musical qualities that lead us to choose terms such as 'timelessness' and 'stasis' as suitable metaphors for music. This is followed (section three) by a discussion of linear and nonlinear forms of contemporary music, the categorisation of which provides a framework for exploring how contemporary composers have challenged traditional aspects of time and motion in music (section four). Although the boundary between linear and nonlinear forms is inevitably penetrable, I have isolated the characteristics of Steve Reich's phase-shifting music that defend its position in the nonlinear, 'vertical' time category (section five). The contribution of repetition to the 'vertical' time sense invites a discussion of how listeners interact with the texture of the musical work. The notion of verticality removes the traditional function of beginnings and endings in music, and sets up a system where consistency forges an arena for changing perspectives. Again, the discussion returns to the disparity between a seemingly invariable system and the resulting destabilisation of the listener's percept.

The notion of *deconstruction*, which involves the dismantling of structuralism, is introduced in Part Two of the chapter to examine this contradiction (section one). In my view, Reich's phase-shifting music represents, unintentionally or not, an idealisation of Derrida's outlook by creating a system where patterns are perceived to emerge from the past and dissolve into the future. In order to consider the significance of the 'thing' that causes patterns in music to emerge and disappear, the discussion is directed to the concept of an 'intertext'. Visual examples of figure/ground reversal are discussed in the chapter because I believe that they provide an insight into the relationship between patterns in awareness (figures) and patterns excluded from awareness (ground). These examples are used to discuss similar experiences in the auditory field, and their various manifestations in Reich's early works (section two). Section three of Part Two considers the nature of phase transitions, and looks for similarities between the effects generated by such transitions in both the visual and auditory medium.

In my view, an understanding of the participation of pattern in the perception and experience of Reich's music is benefited by sketching out the relationship between auditory illusion, pattern, and 'meaningful' music (section four). This relationship constitutes an important theme throughout the thesis. By comparing the nature of pattern in its own right, to pattern as a means of constructing a musical experience, attention is drawn to the nature of the perceptual processes required to organise the stimulus. The role of these processes is discussed in the final section of Part Two in relation to David Schwarz's notion of the "Listening Subject", which represents what I consider to be an important culmination of experiential dimensions, that is, text, listener, and culture.

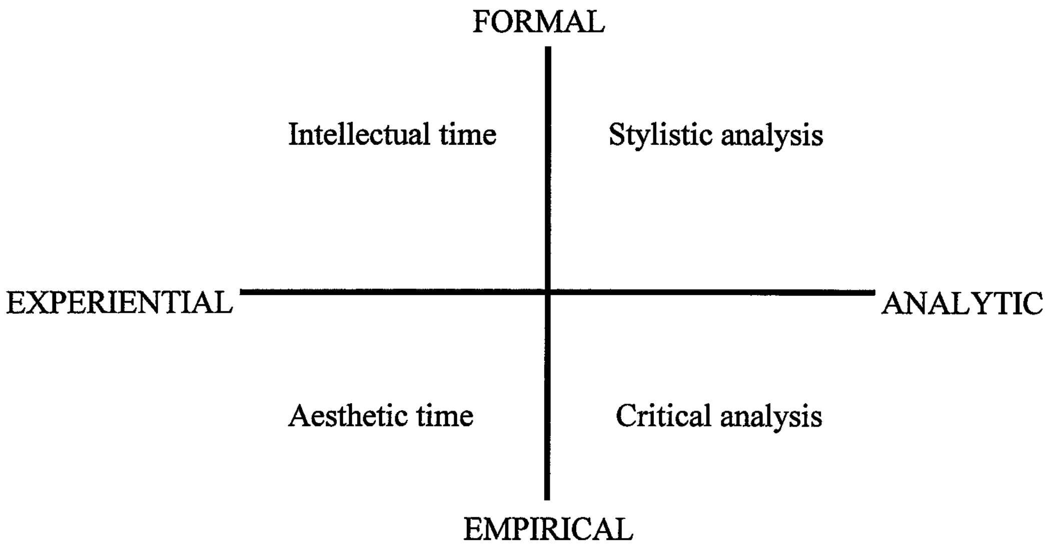
Part One: Stasis in Music vs. Musical Motion

Analytic Platforms

Before discussing aspects of linearity and nonlinearity in contemporary music, and the terminology used to describe 'timeless' music, it is important to consider various theoretical approaches to musical time. When dealing with the temporal nature of music, there are several analytic platforms from which temporal perspectives can be formed. By restricting an analysis to only one of these platforms, only one viewpoint will be obtained. That is, the analysis will only describe one surface of the multifarious subject. Conversely, I propose a multi-dimensional view of temporality in Reich's music, based on an investigation of both internal structures, and perceptual grouping processes. In *Musical Time: The Sense of Order*, Barbara Barry (1990) identifies four interpretative viewpoints of musical time, which together, can be conceptually mapped onto a time matrix (see Figure 2-1).

Figure 2-1 Analytical paradigm for musical time

Source: Barry, 1990, p. 84



In order to appreciate the continuum between musical motion and the impression of stasis in music, the theory of musical time itself should be somewhat nonlinear in order to accommodate its scope. The four analytical viewpoints shown in Figure 2-1 represent a multifaceted interpretation of musical time. The two types of analytic time on the right side of the diagram represent more objective approaches. Barry states that the formal/analytic region "would include those kinds of 'stylistic analysis' which project the work against an abstract background of normative characteristics and examine to what extent it exemplifies those stylistic features" (p. 84). By contrast, the analytic/empirical region would include methods such as set theory and functional analysis, predominantly concerned with the transformation of musical themes and motives. Barry states that such methods "would regard the work as self-standing phenomenon with its own internal relationships" and are therefore described as critical analyses (p. 85).

The interpretive viewpoints on the left side of Figure 2-1 are largely subjective. The upper region (formal/experiential) "occurs when the work's main interest is pre-compositional or intellectual, as in medieval polytextual motets and twentieth-century works built on constructional plans whose appeal is more to the mind than to the ear..." (p. 85). Barry describes this type of musical time as "intellectual". The fourth region of the diagram (empirical/experiential) includes compositions "whose response consists of a combination of affective and intellectual elements, [and] can be described as 'aesthetic time'" (p. 85).

The inclusion of Figure 2-1 is not to suggest that studies concerned with only one of the regions above are not informative in their own right. Rather, I argue that findings based on one approach are not necessarily reflected across these boundaries. My position is that the extent of compatibility across approaches to musical time is sensitive to the interval between inherent and perceived structures. The distinction between "objective investigation [and] continuous experience" (p. 86), suggested in the diagram, is clarified by Barry:

> In analytic musical time the work is regarded as object, in order to demonstrate its components and relationships by means of an analytic method or procedure which interprets the work's organization usually from one point... of view - for example, motivic construction, serial organisation, rhythmic structure, pitch classes and set theory aggregates. The converse of this, experiential musical time, considers a work as musical/temporal experience; it is concerned with how inherent and individual factors are inter-related, what factors contribute to the affective response, and how musical time passes. (Barry, 1990, p.86)

In my opinion, conflicting views about the analysis, and consequently, the temporal nature of Reich's music (to be reviewed in Chapter 4) can be bridged by considering the interaction of the various approaches identified by Barry. By addressing traditional musical analysis, *and* an exploration of the perceptual mechanism, the present research aims to provide a contextual framework for Reich's music based on both the objective and subjective dimensions of temporality. A detailed investigation of perceptual processes specifically to explore the notion of stasis in music has not yet been conducted. I believe, however, that this approach is significant, in terms of resolving many of the discrepancies inherent in commentaries on Reich's music, and its place in the contemporary repertoire.

In much contemporary music, the temporal experience is defined by the interaction between the listener and the musical texture, which offers a wide range of perceptual possibilities. This can be contrasted with more traditional linear compositions, which are constructed so as to dictate the temporal direction of the listener. As stated by James Boros (1994), "such music is authoritative, in the sense that [it is] constructed with a definite result in mind" and often forces the listener to employ their "perspective faculties in one particular way" (p. 97). Similarly, Susan Sontag compares works "to which the audience can add nothing," with compositions "of sufficient, controlled complexity" which may "be perceptually infinite for a given listener" (p. 115).

These distinctions are explored in the following sections through a discussion of temporality in contemporary music. The aim is to provide an insight into the complex relationship between linearity and nonlinearity, and motion and stasis, which will serve as a backdrop for the musical and perceptual analysis of Reich's music presented in Chapters 4, 5 and 6.

Musical Metaphors: Motion and Stasis

The aim of this section is to consider the properties of music which inspire the use of terms such as timelessness, stasis, and ateleology[1] as metaphors for music and musical experience. One approach to uncovering the properties of music which lead to the impression of 'timelessness' is to review the concept of musical motion, and search for paradoxes. Lewis Rowell (1987) questions how "such a notably mobile phenomenon as music [can] project the illusion of stasis" (p. 181). His approach is to explore the notion of stasis from the perspective of semiotics. The inherent contradiction in the phrase 'stasis in music' requires that clear definitions of stasis and motion be sought. Rowell claims that the problem is complicated by the tendency of composers and analysts to "think of music in 'parables' and describe music in the language of metaphor, since any verbal account of music must

[1] The terms anti-teleological and nonteleological (Kramer, 1988, p. 385) have also been used, although their meanings have slightly different connotations. Ateleology implies an absence of progressive relationships. Anti-teleology, on the other hand, implies a reaction against them. The distinction between the two can be likened to the difference between 'atonal' and 'anti-tonal'.

necessarily be a metaphor" (p. 181). Rowell describes the 'meaning' of stasis in music as:

> an idea, a stimulus, a cultural model of some aspect of the 'timeless' that a composer has in mind before and as he works - which, to the alert and imaginative listener, may evoke some similar image of timelessness and which will, to even the casual listener, resist interpretation as 'dynamic passage through time. (Rowell, 1987, p. 182)

The source of the static experience, which might be "an idea, a stimulus" or a "cultural model", reinforces the importance of the four interpretive viewpoints (analytic, formal, empirical, experiential) shown in Figure 2-1. In Chapter Four of this thesis, I demonstrate that the presence of linear progressions, uncovered by traditional analysis, are often negated perceptually by the participation and interaction of other parameters.

The definition of motion in music is potentially problematic. Motion can be thought of as "any continuous change in quality, quantity, or place" (Rowell, 1987, p. 182). Rowell also cites William of Ockham's definition of motion as "merely a name for the set of successive positions occupied by the mobile" (p. 182). The problem with this definition concerns agreeing about what it is in music that is mobile. The concept of motion in music hinges on the relationship between the listener of the work, and the musical work itself. In answer to the question, 'what is it that is mobile' in music, Rowell suggests that:

> Thinking, playing, and hearing music involve many types of motions - vibratory, neural, molecular, muscular, and the motions of physical objects - but this is not, I think, what we mean when we speak of musical motion. If it were, stasis in music would be inconceivable, in fact or fancy... What we usually describe as motion in music is a kind of *locomotion* (change of place), requiring the listener's present as a point of reference and his recognition of the identity of the state of the music as that which is mobile. (Rowell, 1987, p. 182)

By contrast, this suggests that in static music the listener is not provided with any cues which could be interpreted as references to the past. Similarly, expectations in static music are eliminated through saturation (repetition), or by the presentation of a series of randomly ordered tones which do not allow the listener to form linear relationships between successive events. In tonal music however, the characteristics of tension and release, brought about by suspension and resolution, propel the listener forward. Jonathan Kramer (1988) expresses a similar view to Rowell in his discussion of the term 'tonal motion':

> Nothing really *moves* in music except vibrating parts of instruments and the molecules of air that strike our eardrums. But the metaphor is apt. People who have learned how to listen to tonal music sense constant motion: melodic motion, motion of harmonies toward cadences, rhythmic and metric motion, dynamic and timbral progression. Tonal music is never static because it deals with constant changes of tension. Even when there is a passage of suspended harmonic motion, we listen expectantly for the desired resumption of progression. (Kramer, 1988, p. 25)

In linear tonal music, despite passages of "suspended harmonic motion", we develop and revise expectations, anticipating future events until our projected goals are reached, or alternatively, rejected. As stated by Rowell, musical "motion may be intermittent, may be at a steady or variable rate, but we perceive a continuous musical identity moving past our field of hearing" (p. 182). What Rowell describes as a kind of 'vehicular' motion, is projected in traditional Western art music by "thematic means, superimposed on a metrical system of stresses, and activated by the changes in the rate of beats and events, as well as by the implicative powers of tonality - the principle that leads us to predict a specific tonal goal" (p. 183).

If tonal motion, as Rowell suggests, represents the most significant temporal force in Western art music, (p. 183), then the concept of music as an 'art of motion' was significantly threatened with the introduction of atonality in the late 19th and early 20th centuries. Although the notion of obscuring and distorting time is a characteristic of music over many centuries, it is only in the twentieth century that we find examples of music which project, in their entirety, a sense of apparent stasis. The shift away from linearity is expressed by Christian Wolff (cited in Nyman, 1974) in reference to the experimental and avant-garde music of the 1950's:

> Complexity tends to reach the point of neutralization; continuous change results in a kind of sameness. The music has a static character. It goes no particular direction. There is no necessary concern with time as a measure of distance from one point in the past to a point in the future, with linear continuity alone. It is not a question of getting anywhere, or making progress, or having come from anywhere in particular, or tradition or futurism. There is neither nostalgia or anticipation. (Nyman, 1974, p. 23)

The means by which composers have achieved this "static character" are diverse. The impression of stasis has been achieved in contemporary music through ostinato repetition, the construction of dense musical textures, random ordering of tones, streams of unrelated sounds, sparsely saturated sound fields, extreme temporal ambiguity, and aural collage (Rowell, p. 186). Composers such as Stravinsky, Reich, and Terry Riley, have created compositions in which loops of sound permeate the listener's field of hearing. The use of the word 'field' to describe the musical space is a sign of changing temporality - one that envelops spatiality and depth rather than progression. Other compositions which use texture as a principle compositional device include the 'sound masses' of Schoenberg, Ligeti and Xenakis. Occasionally, the static quality of a composition is established in real-time performance, such as in works by Stockhausen, where "performers may follow a minimal script but with most specific decisions improvised during the performance in response to what is perceived as an unfolding situation" (p. 186). Alternatively, sounds or events which fill a silent background are arranged so that the distance between them is significant enough for coherent, linear patterns not to be formed. Rowell summarises the significance of new metaphors for music, such as collage, complexity, sound masses, saturated sound fields, timelessness, ateleology, and stasis:

> the idea of organic, living substance is no longer the inevitable model for music; that music may be conceived in terms of spatial volume and mass

> rather than temporal duration, sequence, and flow; that music may imply the singularity of the detached moment, stasis instead of continuity, and may lack any significant internal structure and articulation... (Rowell, 1987, p. 193)

One way to assess the different types of 'static music' that have emerged throughout the twentieth century, is to explore the variety of ways in which composers have utilised combinations of linear and nonlinear elements in their music. New combinations and manifestations of linearity and nonlinearity in music have consequently brought forth a range of new temporalities which have broken the mould of traditional, predominantly linear Western art music.

Musical Directions: Linear and Nonlinear Forms

This section includes a general discussion about the nature of linearity and nonlinearity in music, and considers the extent to which the 'temporality' of music can actually be classified. In the next section, I discuss Kramer's (1988) categorisation of nonlinear music which includes 'multiply-directed linear time', 'moment time', and 'vertical time'. These categories were developed to assess the variety of ways in which contemporary composers have broken away from the constraints of linearity. The vertical time category, in which Reich's early music has been placed (Kramer, 1988), is discussed in a separate section according to a range of defining criteria.

In music, linear and nonlinear characteristics can exist together on different levels. For example, Kramer acknowledges that music can be "linear on a deep structural level yet nonlinear on the surface" (p. 6). Conversely, a composition constructed using a nonlinear procedure may generate a surface from which listeners can extract coherent patterns from successive events.

I adopt Thomas Clifton's assertion, cited in Kramer (1988), which is that "time is not an independent process but a relation between a person and an experienced event" (p. 6). This suggests that what might be nonlinear for one listener might be linear for another. For example, in serial music, an intimate knowledge of the work on a compositional level may permit a comparatively linear experience, because familiarity promotes expectation and anticipation. Without this knowledge, however, the notes may appear as a string of randomly ordered tones, in which one permutation of the series bears no relationship to any other. A similar perspective is offered by Barry (1990), who suggests that rather than considering how time passes in music, we should consider "how time is understood to pass":

> The factors affecting understanding lie in the matching between inherent complexity and organisation and in the "human factor": between object articulation and formal intelligibility, enlivened by ambiguity or the unexpected (deviation) on the one side, and individual ability (personal complexity level), taste (individual preference), the group factors covered by the term "arousal potential" - liking, familiarity, attention and incentive - and memory, on the other. (Barry, 1990, p. 72)

The relationship between linear and nonlinear music has been described as analogous to the philosophical distinction between 'becoming' and 'being' (Kramer, 1988, p. 16; Rowell, 1987, p. 183) As mentioned previously, tonal progression is considered to be the most powerful motional force in music. Similarly, Kramer links the role of tonal progression with the notion of 'becoming':

> In music the strongest representative of becoming is tonal progression, though any movement through time, whether goal-directed or not, exemplifies becoming. I identify becoming with temporal linearity. Nonlinearity is more like being. Nonlinearity is a concept, a compositional attitude, and a listening strategy that concerns itself with the permanence of music: with aspects of a piece that do not change, and, in extreme cases, with compositions that do not change. (Kramer, 1988, p. 19)

Linearity and nonlinearity usually act as simultaneous forces in music, operating on different hierarchical levels. The most radical departure from traditional musical time, which involves a balance of suspension and resolution (linearity and nonlinearity), are those works which take either concept to the extreme. This point is reinforced by Kramer, who states that the interplay between linearity and nonlinearity "determines both style and the form of a composition" (p. 20).

Linearity is defined by Kramer as "the determination of some characteristic(s) of music in accordance with implications that arise from earlier events of the piece" (p. 20). The term 'implication' suggests process, in terms of some progressive relationship between events over time. This definition highlights the complexity of the relationship between linear and nonlinear elements in Reich's phase-shifting music - a music based on a well-defined process in which the outcome is largely nonlinear. In the following chapters of the thesis, this relationship is further explored by considering the integral role of the perceptual mechanism which governs the grouping of successive events in time. If linearity is processive, then nonlinearity is independent of process. Kramer describes nonlinearity as the "determination of some characteristic(s) of music in accordance with implications that arise from principles or tendencies governing an entire piece or section" (p. 20). Most importantly, these principles do not develop from earlier events. Kramer's classification of musical time into 'directed linear time', 'non-directed linear time', 'multiply-directed linear time', 'moment time', and 'vertical time', are based on different types of interaction between linear and nonlinear time. The first two categories, directed linear time, and non-directed linear time, are discussed below.

Linearity is a feature of both tonal and atonal music. Linearity in tonal music refers to the functional relationships between successive events such as tonal progressions, phrase structure, cadence points, durational proportions, repetition and theme variation. Conversely, linearity in atonal music is defined by characteristics other than tonal progression. The move toward chromaticism in the late 19th century is attributed to the increase in "the urgency of music's goal-directedness", and the "disappearance of background tonal harmonies" (Kramer, 1988, p. 32). In this music, the frequency with which projected goals are realised is minimised in favour of suspension and nonresolution. The introduction of atonality generated new ways of creating predictable goals in music that were not based on tonal relationships. These goals may be created "contextually by means of reiteration or emphasis" (p. 38). The works of Webern, Berg, and Schoenberg are all described as demonstrating nontonal pitch linearity. Generally speaking, "much atonal pitch linearity operates on shallower hierarchic levels but not on middleground and background layers" (p. 39).

Kramer emphasises that nonlinearity is also a feature of tonal music. He provides examples of music in which surface features such as rhythmic patterning and motivic material are held constant, such as in Chopin's Prelude in C Major, opus 28, no.1 (1839), and Bach's Prelude in C Major, from the first volume of *The Well-Tempered Clavier* (1722). Another example is Schumann's *Stückchen* from the *Album for the Young* (1848). Although the constancy of these surface features characterise nonlinearity, other features of the music such as tonal progression, phrase structure, and cadence points, contribute to a strong linear sense. Again, different listening strategies may determine whether linearity or nonlinearity dominates the temporal experience.

Although discontinuity and fragmentation are strongly associated with nonlinearity, they also serve an important function in linear music. The complexity of musical temporality is apparent, in that "neither linearity nor nonlinearity is necessarily allied with continuity, discontinuity, or contiguity" (Kramer, 1988, p. 21). This gives an impression of the overlapping nature of categories of musical time. The presence of nonlinearity as a concept requires such overlap for its relevance and absorption, and its inclusion in such a discussion.

While Kramer acknowledges the limitations of his definitions, his categorisations serve as a basis for further investigating the subtleties of musical time. In particular, he suggests that the role of the perceptual mechanism, which determines how expectations are formed or violated by preceding events, must be considered. The categories of musical time discussed in this chapter apply to compositions, listening strategies, conditions of performance, compositional philosophies, and to time itself. Many examples of contemporary music demonstrate characteristics of several different 'temporalities', on a number of different levels. One of the ways to appreciate the range of compositional approaches which have lead to 'timeless' music, is to consider parallel advancements in other areas which may represent catalysts for such change. The following section, therefore, focuses on time categories which are predominantly nonlinear, and discusses the impetus for the distortion of linear time frames in contemporary music. Such an exploration is necessary in order to establish a contextual framework for Reich's music, specifically with regard to his treatment of time.

Contemporary Music: Challenging Traditional Concepts of Time

Revolutions in the concepts of time from the turn of the century have been acknowledged by critics and theorists across all disciplines concerned with temporality. The evolution of time concepts in music can be seen as a reflection of the complexities of modern life. As suggested by Kramer (1988), "we can no longer confidently predict the direction, outcome, total duration, or overall meaning of many of our temporal experiences" (p. 14). More succinctly:

> we see in the twentieth century not a complete reversal of older Western values but rather a maximal interpenetration of the two fundamental opposing forces of existence... we must remember that both being and becoming are fundamental to human time and to its artistic expressions. (Kramer, 1988, p. 18)

The rise of nonlinearity in Western art music in this century has been accelerated by advancements in recording technology, and the influence of non-Western music. Debussy and Stravinsky have been identified as the first composers to abandon "the tension-laden pedal points of Bach for segments of musical time that are stationary and have no implication to move ahead..." (Kramer, 1990, p. 44) The increased interest in "harmonic stasis" in Western music is attributed to the gradual absorption of music from non-Western cultures, for example, the impact of the Javanese gamelan orchestra on composers such as Debussy and Gustav Mahler (Kramer, 1990). The interplay between linear and nonlinear musical time is demonstrated by Mahler's *Das Lied von der Erde* "in the final song of which a decidedly Oriental time sense is played off... against a Western linearity" (p. 44). Despite Mahler's exploration of nonlinear musical time, many German composers, such as Schoenberg and his contemporaries, retained the elements of linearity which dominated their musical heritage (Kramer, 1990).

Charles Ives is another composer who obscured traditional musical linearity early this century. Ives' music is described as evoking a non-directed time sense, unlike his contemporaries who studied abroad and absorbed the linear characteristics of European tonality (Kramer, 1988). Ives' *Fourth of July* (1913), which is constructed in the form of an 'aural collage', is identified by Rowell (1987) as an early example of a composition projecting a sense of stasis.

As stated previously, although discontinuity "in itself does not necessarily result in or from nonlinear thinking..., pervasive discontinuity can destroy linear progression" (Kramer, 1988, p. 45). The appearance of extreme discontinuities is viewed as another significant influence on the nonlinear quality of twentieth century music. The increase of discontinuity in contemporary music can be partially attributed to technological advances such as radio, tape recorders, and records, which offer the listener the freedom to enter and exit any section of a composition at will. As a result of the introduction of this technology, listener's were no longer 'captive' to a presentation of music from beginning to end (Kramer, 1988). It is suggested that the influence of the tape recorder on composition may have stemmed from the realisation that "the musical result of splicing can be overpowering discontinuity" (p. 45). The influence of recording devices on the conception and performance of Reich's music is significant, it will therefore be discussed in the last section of this chapter. Other examples of compositions which use discontinuity as a structural device are discussed below.

Compositions which fall into Kramer's category 'multiply-directed linear time' are pieces in which "the direction of motion is so often interrupted by discontinuities, in which the music goes so often to unexpected places, that the linearity, though still a potent structural force, seems reordered" (p. 46). Although the continuity of motion is apparent, there is no clearly implied goal. Kramer considers Schoenberg's *String Trio* (1946), Debussy's *Jeux* (1913), Edwin Dugger's *Intermezzi* (1969), and Lukas Foss's *Time Cycle* as examples of works displaying multiply-directed linear time. These compositions translate an underlying linearity, despite the fact that they are not presented in a linear fashion. Although they are frequently interjected with temporal 'gestures', which have a tendency to dislocate the progressive temporal path, "through the mechanism of cumulative listening, we reassemble the essential continuity of the work" (p. 161).

While 'multiply-directed linear time' can be described as reordered linear time, 'moment time' (derived from Stockhausen's moment form) is predominantly nonlinear. 'Moment time' is further distinguished from 'multiply-directed linear time' by the absence of formal beginnings and endings: "Rather it simply starts, as if it had already been going on and we happened to tune in on it... moment form ceases rather than ends" (Kramer, 1990, p. 50). Moment form incorporates a series of "minimally connected sections... that form a segment of an eternal continuum. The moments may be *related*... but not connected by transition" (p. 50) Each of the sections in moment form generate a sense of the static. Examples of music which fall into this category are Barney Childs' *Music for Cello* (1964), Earle Brown's *Available Forms I* (1961), Stockhausen's *Momente* (1961-1972) and *Mixtur* (1964). Other examples include Messiaen's *Oiseaux exotiques* (1955), the second movement of Webern's *Symphony* (1928), and Witold Lutoslawski's *String Quartet* (1964). The range of these examples demonstrates that the appearance of moment form is not restricted to specific musical styles. Often in this music, structural coherence is integrated by way of proportional balance, that is, the duration of individual 'moments' and their relationship to the whole.

It is not surprising that the experience of partial stasis in 'moment time' and 'multiply-directed linear time' encouraged more recent composers to explore the possibility of expanding this stasis to all musical dimensions. Compositions exhibiting characteristics of vertical time, discussed below, perhaps represent the most extreme examples of nonlinearity in contemporary music.

Vertical Time

The following discussion of vertical time is divided into six sections: Introduction, Quantising Musical Parameters, Beginnings and Endings, Textural Emphasis, Repetition and Changing Perspectives, and The Listening Mode. Each of these sections considers the extent to which Kramer's vertical time category is suitable for describing the temporal nature of Reich's phase-shifting music.

Introduction

The degree of temporal distortion in a musical work can be measured against a listener's awareness of how much time has passed during listening. Generally, we have an approximate sense of how much 'objective' time has elapsed in various sections of a musical work. This is necessary in order to appreciate the proportions of a composition. When durational proportions are eliminated from the musical work in favour of a seamless musical texture however, our sense of 'objective' time may be significantly distorted.

> In one kind of music... there are *no* proportions, because time does seem to be suspended. This most radical species of musical time is vertical time...: the static, unchanging, frozen eternity of certain contemporary music...' (Kramer, 1988, p. 7)

If time is defined as a "*relationship* between people and the events they perceive" (Kramer, p. 5), then vertical compositions overtly demonstrate the capacity of music to significantly alter, distort, and obscure time. According to Kramer, vertical time is "not measurable by clocks or bodily processes, [but]... *is* suspended by intense listening to vertical compositions" (p. 7). Although the discussion so far has suggested that discontinuity (temporal inconsistency) is central to musical nonlinearity in contemporary music, extreme consistency is also a powerful tool for creating a sense of timelessness in music. While compositions exhibiting 'moment time' contain a series of sections that are internally static, vertical compositions have adopted the characteristics of a single moment as their entire essence:

> When the moment becomes the piece, discontinuity disappears in favour of total, possibly unchanging, consistency. Compositions have been written that are temporally undifferentiated in their entirety. They lack phrases (just as they lack progression, goal direction, movement, and contrasting rates of motion) because phrase endings break the temporal continuum... The result is a single present stretched out into an enormous duration , a potentially infinite "now" that nonetheless feels like an instant. (Kramer, 1988, p. 55)

The use of the term 'vertical' to describe such compositions suggests that simultaneous layers of sound characterise the structure and experience of the music, rather than the ordering of successive events. Although phrase structuring is generally absent from vertical compositions, Terry Riley's *A Rainbow in Curved Air* demonstrates that a lack of phrase structure is not a prerequisite for invoking a vertical time sense. Kramer suggests that "the reason that this piece is heard in vertical time is that its phrases refuse to form a hierarchy and are therefore heard to some extent as arbitrary" (p. 55). Furthermore, in contrast to linear music, there is little differentiation between the weight of cadences, and no distinction made regarding the degree of closure.

By avoiding structural cues, vertical compositions refuse to define time:

> A vertically conceived piece defines its bounded sound-world early in its performance and stays within the limits it chooses. Respecting the self-imposed boundaries is essential because any move outside these limits would be perceived as a temporal articulation of considerable structural import and would therefore destroy the verticality of time. (Kramer, 1988, p. 55)

Kramer suggests that "vertical music may be defined by process as well as stasis" (p. 57). Although process is usually associated with linearity, the rate of the process, the consistency of musical material, and the nature of perceptual grouping processes, may reduce the likelihood of process being interpreted as progress. For example,

> Compositions such as Steve Reich's *Come Out* (1966) or Frederick Rzewski's *Les Moutons de Panurge* (1969) are constantly in motion, perhaps toward a goal... or perhaps without one, into infinity...One might think of such works as purely linear, but listening to them is not a linear experience, despite their internal motion. (Kramer, 1988, p. 57)

If a sense of linearity is reinforced by occasional movement away from regularity (characteristics of tension and release), then the consistency of vertical compositions seeks to remove any frame of reference from which time, as progression, can be measured. In a sense, the motion in these works is unrelenting. The gradual rate of change, and the avoidance of phrase structure, however, results in a temporally static event.

As mentioned, vertical time is perhaps the most radical departure from traditional linearity in contemporary music. While most nonlinear music retains vestiges of linearity, vertical music is the most resilient. Kramer considers John Cage's *Variations V* (1965) to be a vertical composition. This work is described as approaching the "infinite ideal where *anything* can happen without upsetting the verticality of the time structure" (p. 56). Another example is Cage and Lejaren Hiller's *HPSCHD* (1969) which involves "a great density of layered sound, with myriad of possible relationships between simultaneous layers" (p. 56).

Other sources of vertical music, which were composed in the 1960's, include "Stockhausen's *Stimmung* (1968)...; the conceptual works of La Monte Young and Philip Corner; early minimalist music like Steve Reich's *Violin Phase* (1967); Philip Glass's *Music in Fifths* (1969), and Rzewski's *Les Moutons de Panurge* (1969)..." (p. 386). Other vertical compositions by John Cage include the *Variations*, *Cartridge Music* (1960), and *Atlas Epicticalis* (1962). According to Kramer, Morton Feldman is the composer whose music best represents vertical time:

> While Cage remained concerned with the compositional process, which can be linear even when the resulting music is not, Feldman simply put down one beautiful sound after another. Feldman's aesthetic had nothing to do with teleology... (Kramer, 1988, p. 386).

Early reflections of vertical time can be found in music composed prior to the 1950's. For example, elements of verticality are present in Webern, Stravinsky, and Messiaen. Other early examples include Satie's *Vexations*, and Charles Ives' *In the Night* (1911) (Kramer, 1988).

Quantising Musical Parameters

Timeless music can be seen as adhering to a set of rules which resemble rejections of traditional dynamic properties of music. For example, it can be described as:

> consistent, continuous, and relatively unarticulated; it fails to imply a sense of progression, goal direction, increasing or decreasing tension, movement, hierarchy, structural functions, contrasting rates of motion, cumulation, phrases, or other internal units that might suggest a temporal scale of periodicities. (Rowell, 1987, p. 184)

Essentially, these laws include removing any nuance or colouration from performance which might promote temporal shaping. These compositions remove the traditional cues which usually evoke responses based on familiarity, knowledge, and cultural sensitivities. That is, the schema-based processes which are largely responsible for our understanding and appreciation of traditional linear forms of music, are not active in the same way when listening to vertical music.

In Reich's phase-shifting music, the *avoidance* of:

- hierarchical phrase structuring
- formal beginnings and endings
- defined sections
- pitch and dynamic changes
- variation in articulation, and
- tempo and key changes

represents a quantisation of musical parameters which removes the characteristics of music which are responsible for shaping the temporal continuum. In addition, the subtleties of human performance are minimised by the instruction for 'mechanical playing'.

Beginnings and Endings

The infinite nature of vertical compositions suggests that their onset does not represent their beginning, but rather the point at which they are tuned into by a listener. This suggests that vertical compositions create the impression that they are ever-present, however, sometimes they are in awareness, and at other times they are not:

> Such a piece neither begins nor ends - it just quits. A part represents the whole, and the piece may be of any length. The general illusion is one of a state rather than a process, a music more of being than becoming, a continuous Now. (Rowell, 1987, p. 184)

Similarly, vertical music can be seen as starting rather than beginning, and ceasing rather than ending (Kramer, 1988). The word 'ceasing' implies that the moment at which the piece ends signifies an interruption, pause, or suspension rather than closure. The end of a vertical composition creates the impression of 'tuning out' of an eternal soundscape. The resistance to accept its completion is confounded by the lack of direction and forward motion throughout the piece: how can it end when it hasn't even started?

Reich's phase-shifting music begins with the cyclic repetition of a principle pattern. This pattern continues, consistently, for the duration of these compositions. The characteristics of the principle pattern and its permutations, which are sounded simultaneously, are concordant. That is, their notes are equally weighted, their articulation identical, and their dynamic value the same. Although Kramer describes Reich's *Violin Phase* as "uncompromisingly vertical" (p. 386), there are sections of this composition which give precedence to specific melodies, the notes of which are "participants in progression" (p. 55). These are the melodies described by Reich as "resultant patterns", which are based on sub-melodies derived from interlocking patterns, and emphasised through instrumental doubling.

Textural Emphasis

The consistency inherent in vertical compositions creates what Rowell has described as "a pool of sound, a sustained aesthetic surface in which the beauty lies in one's response to the surface itself, not in the syntactical relationships among its components" (p. 184). By stripping music of its directional qualities, the listener is left to contemplate the textural essence of the composition. Our attention is not drawn to privileged features of the music, rather, we search for relationships and explore the boundaries of the auditory space or field that we are presented with. Because the boundaries of that space are well defined by repetition, and therefore fixed, we are held in place - in the context of Reich's phase-shifting music, in a place where temporal relationships may only exist within (and therefore be defined by) streams of the auditory field. Although we can only attend to one temporal stream at a time, we are aware of the existence of the other(s), and participate in the experience of shifting from one percept to another. The nature of perception itself, specifically, its limitations and freedoms, adopt a heightened role in the exploration of this unchanging musical texture. Patterns are not strictly dictated by the composer, but a variety of possible patterns, which may be selected or rejected by the listener, emerge from the texture itself. The capacity of this kind of music to house the listener's experience in a spatial vortex, rather than in a 'dynamic passage through time', is addressed by James Drew, who states that "...the overall motionless of this kind of composition now brings sufficient attention to the space in which *all of its information is constantly being revealed*" (Barry, 1990, p. 265). Similarly, Barry comments on compositions which emphasise "time as space":

> ...the negation or suspension of time appears either through an extended textural continuum, which mostly approaches the motionless extension of eternity, or by passage through the "point" present, which reflects through its snapshot succession assembled fragments of the total potentiality of the [time] matrix. (Barry, 1990, p. 272)

Textural density is used as a structural device in compositions other than those which fall into the vertical time category. Works such as Ligeti's *Atmospheres* and Penderecki's *Threnody for the Victims of Hiroshima* are examples of compositions in which textural change ranges from single lines to dense clusters of sound. Barry suggests that "the more events are subsumed into expanding and contracting texture bands... then the more individual characteristics will tend to be swallowed up, and the less time will be articulated" (p. 259). The focus in such music is between simultaneous events, which occur in a stable continuum.

While motion is defined by the articulation of time, textural bands are characterised by the extension of space. Barry highlights the fact that "although the medium is, of course, time, here its predominant *perceptual quality* is not direction, but spatiality" (p. 259). In summary, space is revealed by a lack of temporal articulation. What makes vertical compositions unique is that their textural variation does not provide strong enough cues to evoke a linear time sense. In the analysis of Reich's phase-shifting music (Chapter 4), textural density is discussed in terms of attack-point frequency, where the influence of attack-point design on the listener's temporal experience is considered in detail.

Repetition and Changing Perspectives

The repetitive nature of Javanese gamelan and the consistency of African drumming or xylophone music, has had a notable influence on different types of contemporary music. Such influences can be found in the music of Satie, Ravel, early Cage, and Messiaen, however Dennis (1974) suggests that it is explored "more conspicuously... in repetitive music" (p. 1036). Similarly, repetitive music reflects, most strongly, the "psychoacoustic nature of multi-repetition" and visual art "where powerful rhythms produce a host of vibrant shapes different for each viewer and his separate vantage point" (p. 1036).

Repetition, as a compositional device, when taken to the extreme, acts as a catalyst for changing perspectives. While the musical 'object' is laden with consistency, the perspective for the viewer may be in a constant state of flux. This apparent contradiction is explained by the fact that the events in flux, which are usually associated with linearity, do not exist on a single time line defined by successive events, but rather between time lines, which are segregated by the perceptual apparatus. Dennis makes several observations about the ability of repetitive music to shift the perspective of the listener. In his view:

> even with smoothly phased pieces like the electronic loop pieces of Steve Reich, the rhythms seem to 'jump'. The strong counter-rhythms and contrasts which are built into the process... are heard at different times by different people. The 'jump' is often the sudden awareness of a change which has

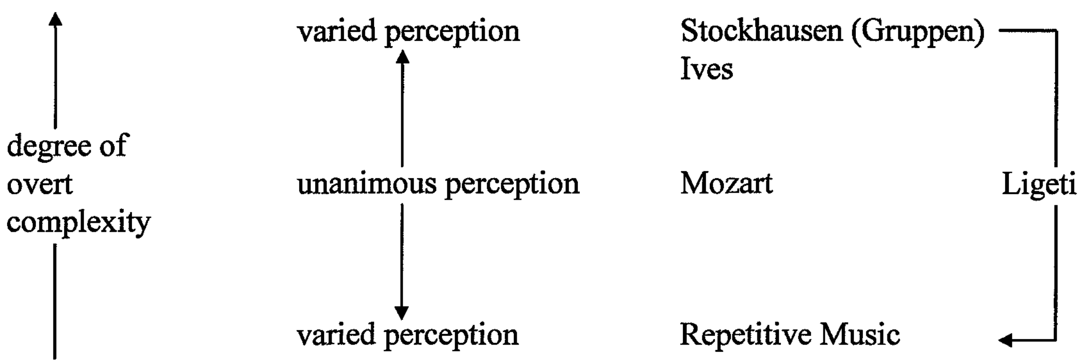
taken place gradually. (Dennis, 1974, p. 1036)

The concern of most repetitive and systemic music is with compositional processes that allow the consequences, or "side-effects to take care of themselves" (Dennis, p. 1036) These 'side-effects', or in Reich's terms, 'psycho-acoustic by-products' allow perceptual variation to occur despite the fact that the music is unchanging. The question which is addressed throughout the thesis, is: *Are the resulting patterns (side-effects) perceived in Reich's phase-shifting music a result of primitive processes of organisation, or perceptual processes which are governed by familiarity and learning, that is, musical schemas?* This question is addressed by turning specifically to the listening mode, and by addressing the complex nature of the perceptual mechanism.

The Listening Mode

An exploration of varied perception is necessary to highlight the experimental nature of contemporary music. Dennis uses the example of a clear-textured Piano Sonata by Mozart where our aural perception of the piece is relatively unanimous. This is compared with music of "greater horizontal and vertical complexity" where "our hearing becomes selective so that our perception of, say, Messiaen's Epode in *Chronochromie* differs from person to person at any one time" (p. 1036). This type of selective hearing is an important feature of repetitive music, despite the fact that the texture of the music remains relatively constant.

Figure 2-2 Perceptual Variability in Relation to Compositional Complexity
Source: Dennis, 1974, p. 1036



Dennis' model, shown in Figure 2-2, suggests that on a continuum from simple to complex, the phenomenon of varied perception is strongest at each of the extremes. In this context, the word unanimous should only be understood relative to the concept of varied. The level of complexity in music, like the notion of temporality, can be judged on a number of different levels. Judgements of complexity can be made according to levels such as information processing, pre-compositional planning, external references, compositional philosophy, or the magnitude of the work. The relationships suggested in Dennis' model are based on "overt" complexity, which implies a level of complexity existing on the surface of the composition - a more objective evaluation. Chapter 7 of this thesis addresses the notion of musical complexity specifically with regard to Reich's music.

One of the most interesting features of repetitive music, such as Steve Reich's phase-shifting music, is that it does offer varied perception. That is, variation between consecutive listenings, and among different listeners. Dennis discusses the notion of alternative 'views' in Reich's *Piano Phase*:

> ...as regards shifting accents one may sense a new downbeat in the second appearance of a figure, then one's attention may switch to the downbeat one had 'identified' earlier. As with a flat cube, one can oscillate between two separate 'views'. These are just a few of the complex ways one might listen to this piece tracing the continual shifts of melodic and rhythmic interest, the dominance of certain notes or chords and the ambiguity of accent. (Dennis, 1974, p. 1037)

In perceptual terms, the 'views' Dennis refers to are influenced by auditory stream segregation. The source of perceptual ambiguity, which is a key feature in Reich's music, is discussed in the following chapter of the thesis with reference to literature on auditory and music perception.

The role of attention also plays an important role in listening to vertical (repetitive) music. Rowell highlights several important points about the listening mode, and its impact on the experience of the music:

- short excerpts are not enough to demonstrate the accumulating sense of musical stasis;
- much of the music depends on the full range of the spectrum for its effect (because the primary focus of one's attention falls upon the quality of sound *per se*)
- those whose aim in hearing music involves "synoptic comprehension" will experience more frustration than those who practice "the mode of immediate apprehension" (Rowell, 1987, p. 185).

Listeners of traditional Western art music are likely to have a conditioned bias toward linearity. Similarly, we have a bias for coherence as opposed to segregation. Often, in the absence of linearity, we project our ideas about what 'should' be there. Bruno Repp (1992; 1995), for example, argues that musically experienced listeners project expectations of expressive performance on quantised presentations of music. The relationship between musical culture and listener expectation suggests that Western listeners will tend to listen teleologically. This is a result of the prevalence of linearity in many aspects of our culture. When the causal relationships that we look for are denied, "implications accumulate with a minimum of consequences, because the composition contains no changes of structural import" (p. 56). When our propensity toward linearity is dissatisfied as expectations continue to be unfulfilled, we "either give up expectation and enter the vertical time of the work - where expectation, implication, cause, effect, antecedents, and consequents do not exist - or become bored" (Kramer, 1990, p. 56).

The absence of referential meaning or external symbolism in vertical music presents the listener (and the analyst) with the option of exploring its spatial parameters. Kramer likens the experience of vertical music to looking at a piece of sculpture where we are free to move around the piece and to view it from many angles. We may choose to concentrate on detail, broaden our perspective, look at the relationship between elements of the piece, or look at the relationship between the piece and the space around it. In this sense, the temporal sequence of different perspectives is unique for each listener, in that vertical music "has no internal temporal differentiation to obstruct our perceiving it as we wish" (Kramer, 1988, p. 57). As mentioned previously, the validity of this statement can be further investigated by a consideration of the primitive and schema-based processes which govern the range of patterns that we can extract from the musical texture. These processes are introduced in Chapter 3, and discussed with specific reference to Reich's music in Chapters 5 and 6.

A similar response is evoked by the comment that vertical music "tries not to impose itself on the listener, nor to manipulate... an audience" (Kramer, p. 57). Vertical music is not authoritative in the sense that it dictates the note-to-note direction of the composition, but sets the parameter boundaries which determine the range and scope of available patterns. The individual's perception, and their interaction within the constraints of the musical system, dominates the musical experience. There are, however, sections of Reich's *Violin Phase*, and *Phase Patterns* which intentionally clarify the audibility or perceptibility of specific melodic lines. Relative to many other forms of music however, the extent of imposition is extremely minimal.

One of the primary aims of the thesis is to investigate how pattern participates in the construction of the musical experience in Steve Reich's phase-shifting music. The term *construct* emphasises "the active interaction between the perceptual aspects of information processing, recognition, and memory, and the work's inherent structure" (Barry, 1990, p. 71). Reich's phase-shifting music demonstrates a strong relationship with certain philosophic ways of thinking, and has strong parallels with the phenomenon of figure/ground reversal in vision. Part Two of this chapter explores these parallels.

Part Two: The Free Play of the System

Deconstruction: Questioning the Need for a Stable Centre

In Part One of this chapter I reviewed a range of compositional devices and musical forms which have been used by contemporary composers to obscure traditional concepts of musical time. Elements of linearity and nonlinearity, in many cases, operate on different levels of music to create new time experiences. I argued that in order to understand the intricacies of linear/nonlinear relationships in contemporary music, a combination of objective (formal and critical analysis) and subjective (intellectual and aesthetic) approaches should be incorporated into the final analysis.

I have suggested that Kramer's account of vertical time is an adequate description of Steve Reich's early work, and that vestiges of vertical time are retained in many of his later compositions.

Part two of this chapter continues the investigation of the concepts associated with vertical time which make it unique. In particular, I focus on the *experience* of Reich's phase-shifting music by drawing on parallels in the visual medium, and related philosophical concepts, and introduce ideas developed by Jacques Derrida, whose philosophical notion of 'deconstruction' was prevalent in America in the 1960's. I do not argue that *direct* influences between Derrida's philosophical notions and Reich's music can be found. Rather, I wish to highlight the parallel conception of a new way of thinking, and Reich's music which was composed in the same decade.

In a lecture titled "Structure, Sign and Play in the Discourse of Human Sciences" (1966), Derrida advocated a mode of reading which came to be known as 'deconstruction'. Two important works by Derrida which embody this principle are *Writing and Difference* (1978), and *Of Grammatology* (1976).[2]

The idea of structuralism was dismantled by Derrida through his questioning of stable centres. As stated by Powell (1997), "structuralism depends on structures, and structures depend on centres" (p.19). Other French thinkers who represent a period of 'post-structuralism' include, Barthes, Deleuze, Guattari, and Foucault. All of these writers tend to view knowledge (for example, history, anthropology, literature, psychology) as 'textual'. That is, knowledge is composed of words as well as concepts (Powell,1997).

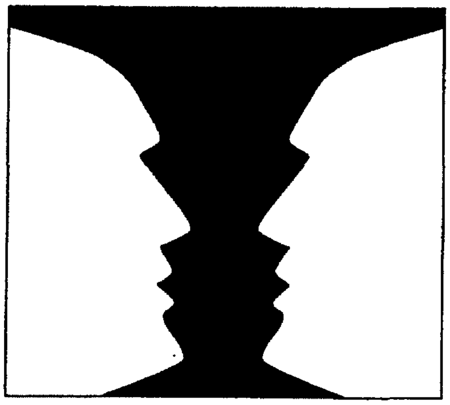
Derrida's notion of deconstruction is concerned with 'decentering'. He sought to reveal the problematic nature of all centres, and suggested that the longing for a

[2] The notion of deconstruction was influenced by a number of prominent philosophic writers including Nietzsche (practice of reversing one's perspective), Freud (questioning the unity of the human psyche), Heidegger (introduced the concept of "Deconstruction"), and Saussure (Swiss linguist who formed the basis of structuralism) (Powell, 1997).

center, which he stated was the basis of all Western thought, spawns binary opposites. The longing for a stable centre is analogous to the predilection for musical linearity in Western culture. According to Derrida, reality and language are not like icons with a central, exclusive image in their middle, but more like ambiguous figures (Powell, 1997, p. 24). This idea can be demonstrated by the well-known image shown in Figure 2-3.

Figure 2-3 Visual example of decentering: two faces or a candle

Source: Bregman, 1990, p. 13



The figure/ground image shown above offers two possibilities. At first we see only one possibility, that is, one is central for a moment. Because the 'play' of the system is not arrested, however, the other view emerges after some time. By manipulating one of the potential figures, it is possible to "freeze or arrest the free play of differences" (Powell, 1997, p. 25). This might be achieved by providing additional visual cues which enhance the dominance of one of the images, such as drawing eyes on the faces. The reality however, is that the figure communicates both faces and a candle. If one of the images is highlighted by additional cues, the other is repressed, and a "hierarchy is formed in which the centralised member of the pair... becomes the privileged member of the pair" (p. 25). This process has been described as freezing the play of the system (Powell, 1997).

The notion of freezing the play of the system is, in a sense, a practice at the core of musical composition. The manipulation of musical parameters allows certain features of the music to dominate the overall texture. For example, a melody might be drawn to the surface of the texture by its distinguishing timbre, articulation, dynamics, or registral characteristics. The more direction (the less ambiguity) given to the listener, the more control the composer has over the results. So, to a certain extent, by freezing the play of the system, the composer governs the temporal direction of a composition. This can be likened to drawing eyes on the faces in Figure 2-3. By providing additional references, the interplay of events within the system is constrained. Reich's phase shifting music however, signifies simultaneous auditory images through the process of phasing. The repetitive nature of his music allows the listener to become aware of two or more pattern possibilities which constantly appear to emerge from the past and dissolve into the future (without specific reference to either the past or the future).

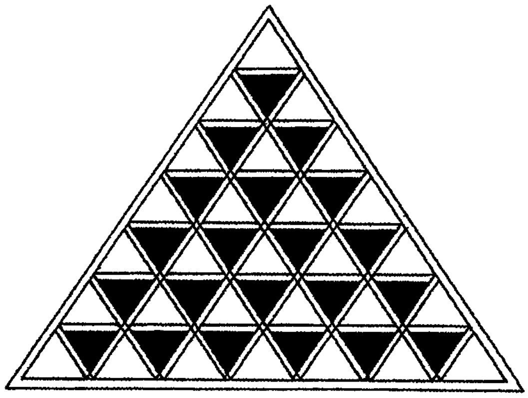
In terms of language, deconstruction attempts to "subvert the central term so that the marginalized term can become central" (Powell, 1997, p. 26). In a sense, Reich has deconstructed the musical system in his phase-shifting compositions, so that both 'terms', and several others, are equally possible. This is an important point, because Reich does not restrict the pattern possibilities to only two alternatives. Rather, there are usually two or three primary figures (or grounds) which may vary slightly on different listenings. Specific examples of these patterns will be provided in the analysis of Reich's music in Chapter 4.

The practice of decentralising musical language, however, has its limits. For example, the perceptual mechanism which governs grouping processes may restrict our ability to integrate, or alternatively, release a note from its melodic context. The idea of decentering, in this sense, is restricted by the thresholds of primitive grouping processes. Within these limits, however, our schema-based perceptual processes enable us to select notes out of auditory mixtures, and integrate them into a new context.

The image of a large triangle containing many smaller triangles, shown in Figure 2-4, offers a series of configurations which present themselves in succession. As explained by Powell (1997), each present configuration "has emerged out of a prior configuration and is already dissolving into a future configuration. And this play goes on endlessly" (p. 29).

Figure 2-4 Visual example of figure/ground reversal

Source: Powell, 1997, p. 29



Again, comparisons can be made with the emergence and disappearance of patterns in Reich's phase-shifting music. The image shown in Figure 2-4 has no central organisation that attempts to arrest the play of the system. Similarly, in most of his phase shifting compositions, Reich does not provide any deliberate structural cues which might otherwise increase the salience of one pattern over another.[3] In Part One of this chapter, I described the notion of removing potentially biased elements from the musical system as 'quantising' the musical parameters. This discussion is continued in Part Three of Chapter 4, which provides a theoretical evaluation of the role of stream segregation in Reich's music.

Derrida advocated that when deconstructed, all language and text (hence human thought) enter a free play which is dominated by the ambiguity of meaning, and that we should continuously attempt to see this free-play in all language and texts - avoiding a tendency toward "fixity, institutionalisation, centralisation, totalitarianism" (Powell, 1997, p. 29). As Reich's phase-shifting music minimises

[3] One exception, to be discussed in detail in Chapter Four, is the presence of doubled patterns in *Violin Phase* and *Phase Patterns*, where the salience of these patterns is purposefully increased. Generally however, the music is dominated by a texture formed by the interlocking of the principle pattern and one of its transpositions. In such regions, the salience of the available patterns is not determined by the addition of stresses such as articulation, dynamics, or timbral quality.

referential meaning and symbolism, and we are left not with the question of *what* the music means, but rather *how* it means. Music cast in vertical time releases individual notes from context, to a certain extent, so that they may belong to part of one pattern, or another. By requesting that the music be played 'mechanically', Reich removes any inflection that might distance the performance too greatly from the 'text'. In the performance of more traditional music however, strict temporal adherence to the score would be considered a bad performance (in the same way that a monotone reading of a text is considered a bad reading). The musical score serves as a guide to expressive interpretation. In vertical music, however, there is no room for interpretation, because any temporal inflection will upset the verticality, and reinstate the question of *what* the text means rather than *how* it means.

The principle of 'dissemination', in Derrida's outlook, involves engaging the reader in the actual process of textuality, that is, in the play of alternative interpretations. Rather than demonstrating textuality, the process of dissemination gets the reader to enter into the space that exists in between two or more possible interpretations. This space both produces and dissolves various interpretations of the text. Similarly, Reich invites the listener to engage in the textural nature of his compositions, that is, the process that allows patterns to emerge and disappear from that texture. The 'spacing', in Reich's phase-shifting music, is the space in between two or more available patterns. In this space, the centralised pattern is both produced and dissolved. In the process of dissemination, "everything happens in the intertext, only one principle is observed: that in the final analysis, what happens is nothing" (Powell, 1997, p. 103). In a literary sense,

> The moment of present meaning, of "content" is only a surface effect, the distorted reflection of the writing..., into which you keep falling, fascinated by appearance, meaning, consciousness, presence in general... (Powell, 1997, p.105)

The concept of the intertext suggests that the emergence of a present configuration is formed by both past and future configurations. This is because one pattern must be submerged in order for another to come to the fore. The written example, "It will have been said", demonstrates this point. Contained in this phrase is an "implied future and a kind of implied past simultaneously, but no present..." (p. 105). The loop is indefinite, only 'ceasing' when we decide to withdraw our attention. Similarly, Reich's phase-shifting works provide the opportunity for listeners to become involved in the process of interacting with the musical texture, the experience of which hinges on the intertext. Similarities between the free play of Reich's music and the dissemination of a written text are suggested below:

> Thus it is always possible for a text to become new, since the blanks open up its structure to an indefinitely disseminated transformation. The whiteness of the virgin paper, the blankness of the transparent column, reveals more than the neutrality of some medium; it uncovers the space of play or the play of space in which transformations are set off and sequences strung out. (Derrida in Powell, 1997, p. 106)

As well as the listener engaging with the music, the music seems to have a play of its own, in the sense that patterns may appear inadvertently. In this sense, there are parts of the listener reflected in the music itself (which generates patterns according to primitive grouping processes), but the listener may also exercise freedom in terms of which of the available patterns they choose to follow. Similarly, in disseminating a written text, the reader and the text become intertwined. The total interdependence of these dimensions of experience in Reich's music are addressed in the final section of this chapter. The context in which patterns may emerge without the listener's volition is continued in the following discussion of figure/ground reversal.

Figure and Ground

In the visual medium, the phenomenon of figure/ground reversal arises when two alternative percepts share a common border. The viewer attributes the border to either of the possible percepts. That is, it is not possible to perceive both at the same time. When a common border is attributed to a figure, the remainder reverts to the 'ground', that is, it provides a backdrop for perceiving the chosen figure. Reversal of the figure/ground object may be the result of attention (forced choice), or may happen inadvertently. The more unstable the system, that is, the more decentred, the less control the viewer will have over the event of figure/ground reversal.

In order to compare the notion of figure/ground reversal in vision with auditory perception, it is useful to differentiate between two types of figures. The first is one whose ground is an "accidental by-product of the drawing act" (Hofstadter, 1979, p. 67) The second is "one whose ground can be seen as a figure in its own right" (p. 67) The latter is demonstrated in Figure 2-5.

Figure 2-5 ***Tiling of the plane using birds*, M.C. Escher (1942)**

Source: Hofstadter, 1979, p. 68

In this example, the interlocking repetitive structure and presence of two distinguishable shades makes figure/ground reversal possible. Similarly, Reich's interlocking patterns and two distinguishable registral ranges set up a figure/ground relationship, where one stream (figure) does not necessarily accompany the other, but rather each pattern is a figure in its own right. This can be compared with music based on melodic figuration and accompaniment, in which the melody is the privileged (most audible) component. Although the high and low patterns in Reich's music are temporally displaced (in relation to each other), they are often heard as existing simultaneously on a different level. That is, although they cannot be perceived at the same time, the exact temporal relationship between them is obscured by the exclusivity of the figure/ground percept. As stated previously, this is made possible by the intentional decentering of the musical system. That is, no one pattern is intentionally manipulated to dominate another.

The difference in the appearance of an area when seen as figure and when seen as ground is clarified by Edgar Rubin (1958), who claims that the ground is characterised by its absence of shape.

> A field which had previously been experienced as ground can function in a surprising way when experienced as figure. This effect depends on the new shape, which had not previously been in awareness, and which is now experienced for the first time. (Rubin, 1958, p. 194)

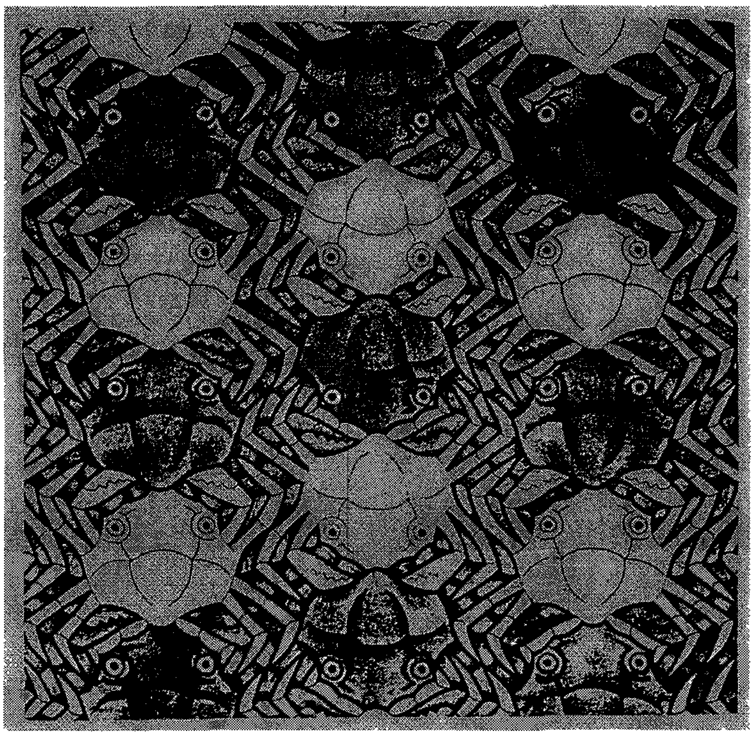
The point of interest, and perhaps the most poignant question associated with figure/ground reversal is: What happens to the ground when it becomes the figure? This question can be approached in reverse, that is, by considering that the experienced object becomes enriched during the transition. Rubin's contemplation of the common boundary between the two fields, results in the following explanation of the relationship between figure and ground:

> when two fields have a common border, and one is seen as figure and the other as ground, the immediate perceptual experience is characterized by a shaping effect which emerges from the common border of the fields and which operates only on one field, or operates more strongly on one than the other. (Rubin, 1958, p. 195)

As suggested earlier, the shaping process itself is not perceived, only its effect. The effect is the emergence, or consequently, the disappearance of a figure. In visual examples, the ground is often perceived as a continuous field extending behind the figure. That is, the ground is "unaffected by the shape-giving function of the contour", and is described as having a "characteristic which is more like a "substance," like flour, sand, iron..." (Rubin, 1958, p. 197).

Figure 2-6 ***Crab Canon*** **(1965), M.C. Escher**

Source: Hofstadter, 1979, p. 198



I have suggested that the introduction of certain cues (relevant to both visual and auditory environments) may create a bias, which directs the viewer's/listener's attention to one side of the double-sided image. In Figure 2-6, the brighter figure seems to dominate, but the eyes of the shaded images are a constant reminder that an alternative arrangement is possible, and simultaneously exists. The legs of the shaded image seem to fit the description offered by Rubin, that is, they provide a granular "substance" which is often associated with a 'ground'. In this sense, the play of the system in Figure 2-6 might be viewed as slightly swayed to one side. The title of Escher's drawing, *Crab Canon*, provides another basis for discussion (Figure 2-6). In music, the idea of a *canon* is that a single theme is played against itself in a number of possible ways. The Baroque fugue is one of the richest sources of canonic techniques. Reich's phase-shifting works, both vocal and instrumental, are also based on a type of canon. The principle pattern on which the canon is based, however, is significantly obscured as a result of perceptual segregation processes, which often divide the duplication of the original pattern into a two-voice texture. In Reich's *Piano Phase*, as stated by Epstein (1986), "we have in effect a series of canons, at distances of from 0 to 11 sixteenth notes, alternating with transitions in which the two voices [two copies of the original pattern] are out of phase with each other" (p. 495). Because of the exact duplication of the principle pattern however, the canon is rarely perceived as such. That is, in most phases, it is difficult to hear the music as two identical melodies that have been separated by some interval in the cycle. If the principle pattern was separated in pitch as well as time (for example, an octave above), the audibility of the canon would be increased. The phase transitions, which bridge each of the stages of the canon, may also distract the listener from its operation.

Phase-Shifting

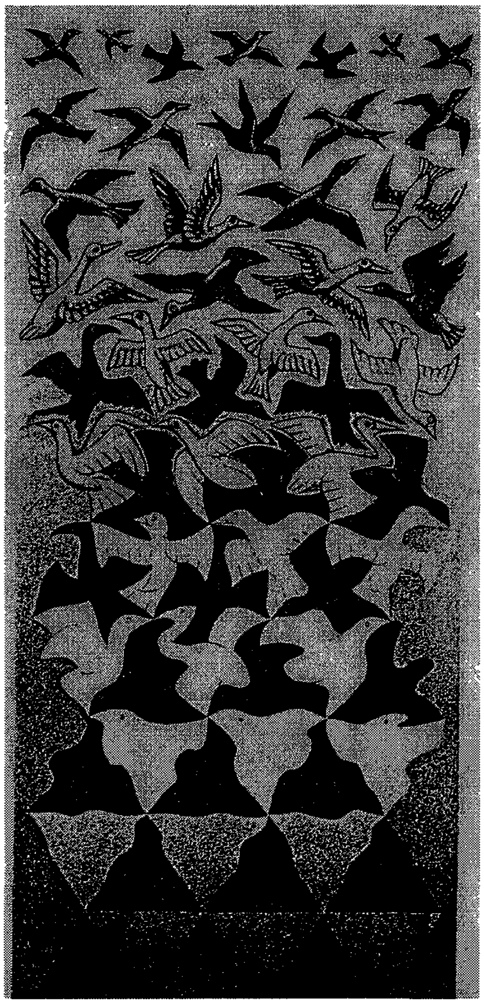
In previous analyses of Reich's phase-shifting music (in particular Cohn, 1992) the accelerating (phasing) regions are given far less attention than the 'immobile' regions. The impact of the phasing regions on the perception of the 'in phase' situations, however, cannot be under emphasised. The lack of scholarly attention given to these regions is understandable. For example, it is difficult to describe the relatively chaotic output of these regions in traditional musical terms. Epstein suggests, however, that certain stages of the phase transitions can be identified:

> The phasing process begins with a movement away from unison. Although continuous, it is heard in several distinct stages. At first the impression is of increasing resonance, a change in acoustic quality only. At the next stage one begins to hear the voices separate: echo replaces resonance. At a certain point the irrational division of the beat caused by the echo presents a dizzying rhythmic complexity... (Epstein, 1986, p. 498)

As demonstrated by the visual example in Figure 2-7 however, the gradual nature of the phase transition makes it difficult to pinpoint the precise moment of change.

Figure 2-7 ***Liberation*, M.C.Escher (1955)**

Source: Hofstadter, 1979, p. 57



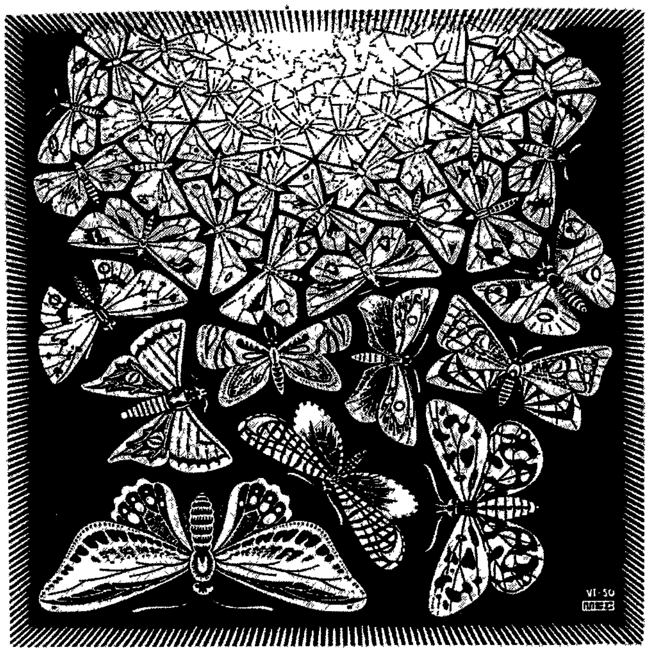
Similarly, in Reich's phase-shifting music, although we can anticipate several distinct stages in the phasing cycle, we are often taken by surprise on their arrival. These stages include the initial splitting of the instrumental voices (originally in unison), and the point at which the phasing process reaches the halfway point. This midpoint, which offers a brief moment of stability, is characterised by what appears to be a doubling of the tempo. Despite our awareness that the acceleration takes place gradually, often these points arrive unexpectedly.

In relation to the transition between phases 1 and 2 in *Piano Phase,* Epstein recognises three significant turning points:

> ...we hear phase 1, with the two voices gradually moving apart; near the midpoint the notes begin to swirl around chaotically, and it becomes increasingly difficult to follow the pattern; but a moment later, the new configuration begins to coalesce, usually well before the instruments actually synchronize again. (Epstein, 1986, p. 500)

These three turning points could describe, equally well, the phase transition demonstrated in Figure 2-8 when viewed from top to bottom. As the 'solid' object begins to fragment, we can identify a kind of circular movement of the images, which then begin to reveal a new configuration. Again, this new configuration begins to coalesce before becoming distinct.

Figure 2-8 ***Butterflies*, M.C.Escher (wood-engraving, 1950)**
Source: Hofstadter, 1979, p. 148



The point at which the moment of change is perceived during the phase transition is likely to vary from listener to listener, and between different listenings. It is also possible to "choose to retain the old pattern a bit longer or jump to the new a bit sooner" (Epstein, 1986, p. 500). Phase transitions, whether demonstrated through the visual or auditory medium, provide important insights into the behaviour of elements when run through the process. We learn about the nature of complex systems, and the way in which our perceptual mechanisms deal with this level of complexity. We gain an appreciation for transformation, and the capacity of the process to generate sudden perceptual shifts.

The illustration in Figure 2-9 captures both a gradual phase transition, and the phenomenon of figure/ground reversal (the configuration of the white images providing the outline of the same images in reverse). Throughout the phase transitions in Reich's phase-shifting compositions, we also experience the depth reversal phenomenon.

Figure 2-9 ***Fish and Scales*, by M.C.Escher (woodcut, 1959)**

Source: Hofstadter, 1979, p. 147

A discussion of the phase-shifting process, which is central to a discussion of temporality in Reich's music, is accommodated by the analytical paradigm for musical time posited at the beginning of this chapter (Figure 2-1). The tools of critical analysis alone do not allow a description of these relatively chaotic regions. Formal analysis, as defined in relation to Figure 2-1, provides only one basis for discussion, albeit an important one, that is, the use of canon (discussed above). The experiential approach, which focuses on the listener's perception of the music, might compare the ways in which listeners group the notes (which are defined at the outset of the compositions) in both the variable and invariable sections of the music. This approach is pursued in Chapter 4 of the thesis.

Figure 2-9 embodies another important relationship that exists in music. That is, the relationship between pattern, illusion, and picture (or in our case 'meaningful' music). Like the relationship between linear and nonlinear elements (discussed in Part One of this chapter), illusion, repetitive patterning, and referential meaning and symbolism, are weighted according to the desired temporal effect. In Figure 2-9, illusion is represented by the gradual emergence of the 'hidden' figures (the negative image created by the white fish); patterning is created by the repetition of the same image; and 'picture' is defined by the representation of an object that exists outside the work of art. The relationship manifests itself differently in music however, because music cannot directly represent something outside itself. The nature of this relationship in Reich's music, and vertical music in general, is considered in more detail below.

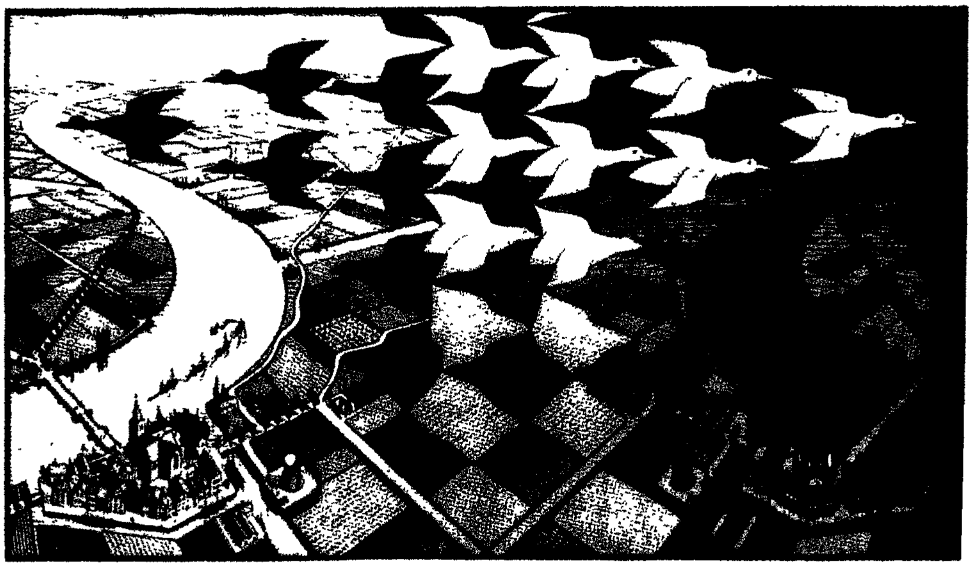
Illusion, Pattern and the Musical Medium

The illustration in Figure 2-10 provides another example of the interaction between illusion, pattern, and picture.

The instability of the figure/ground relationship (strongest in the centre of the composition) becomes more stable as it moves away from the central vertical axis. In other words, the moving away from the centre represents a gradual freezing of the play of the system.

Figure 2-10 ***Day and Night*, by M.C.Escher (woodcut, 1938)**

Source: Hofstadter, 1979, p. 252



As mentioned previously, there are elements in Reich's phase-shifting music which contradict its placement in the vertical time category. In various sections of *Violin Phase* and *Phase Patterns*, the system is temporarily frozen by the introduction of doubled patterns. These patterns are derived from notes of the existing interlocking patterns, and emphasised by a greater dynamic level. The 'pointing out' of these patterns, which are otherwise 'hidden' from awareness, are gradually brought to the fore, and remind us that that they have, in fact, been there all along. The accessibility of these patterns, however, are hindered or enhanced by the nature of our perceptual segregation processes (see Chapters 4 and 6).

J.B. Deregowski's (1984) discussion of the differences between pattern and picture is used here as a basis for a comparison between repetitive auditory patterns and more complex music. Deregowski claims that "meaning is sought and found in pictures" (p. 99). Patterns, on the other hand, reveal "principles of organisation, which are a purely perceptual key to the nature of the design" (p. 99). The word *meaning* in music must be clarified. Rather than through direct representation, meaning in music can be found in emotional responses elicited by music, which arise through the subtle shaping of musical time, and the symbolism evoked by elements such as harmonic progression. The recognition of familiar patterns and structures within music may also provoke external referential meaning.

Deregowski highlights the inclination for searching and organising visual input in both patterns and pictures, in particular, a search for regularity. This takes place independently of whether the "seemingly random elements are representational or geometric" (p. 99). This similarity is further explained in the following comment:

> The dichotomy which exercises the perception is... that between a cohesive and a random pattern, and the perceptual search to which it gives rise is that for cohesive units, which, through repetition and juxtaposition, form the pattern. (Deregowski, 1984, p. 99)

The emphasis placed on the representational role helps to distinguish the difference between a pattern and a picture, and similarly, the difference between repetitive auditory patterns and structurally progressive music. In both cases however, the search for coherence and regularity is fundamental:

> The means by which the eye is caught in the case of patterns are similar to those which entrap it in the case of pictures. In both cases propensities for searching and organising visual input are involved, but the final goal is different. (Deregowski, 1984, p. 99)

The difference in music, is that in compositions based on extreme repetition, the constant rejection of expectation and anticipation leaves the listener with a choice. As mentioned previously, the choice is either to participate in the verticality of the composition, or to abandon it altogether.

The patterns that one hears in Reich's phase-shifting music generate the impression that they are being created by a single sound source. When referring to illusion in Reich's music, I am talking about the integration of notes from two different sound sources, which appear to be emanating from a discrete source (see Chapters 3 and 4). As mentioned previously, a degree of illusion (such as the one described here) is evident in a wide range of musical styles and periods. In most music, these illusory features are much more cursory, often taking the form of figuration. In Reich's music, however, illusion of the nature described above is a key feature of the musical experience. Vertical compositions in general, significantly alter the traditional balance between illusion, repetitive patterning, and progressive music. It should be pointed out, however, that the concept of illusion and repetitive patterning in the music of certain non-Western cultures is far less remote.

Deregowski also points out that "to an observer unfamiliar with the style [of a work of art], any distortions which it may introduce will appear startling and disturbing. A person familiar with the style, on the other hand, may not notice these distortions..." (p. 6). This comment reminds us that a musical composition displaying characteristics of a repetitive pattern may represent meaningful music for one person, and simply a repetitive pattern for another. This also raises the question of how vertical music, specifically Reich's early works, are received by the wider audience, as opposed to those listeners constantly exposed to contemporary (particularly experimental) Western art music. This question is addressed in Chapter 5, which compares the responses of musicians and non-musicians to Reich's music. The distortion in art that Deregowski (1984) refers to can be equated with the temporal distortion of music which was discussed in Part One. The ambiguity of the elements within music or the visual arts obviously allows "a large idiosyncratic influence and hence leads to a greater variety of responses" (p. 7). The importance of listening processes to the experience of Reich's music is highlighted in the following section.

The Listening Subject

David Schwarz (1993) presents "a theory of listening subjectivity for music" (p. 24). His approach is summarised in the following statement:

> ...hearing music as listening subjects qualitatively shifts our focus away from hearing pieces as absolute and self-contained wholes, to hearing music as an embodiment of listening processes. (Schwarz, 1993, p. 25)

Throughout the chapter, I have emphasised that the lack of referential meaning and symbolism in Reich's music heightens the role of different types of listening processes. These are, primitive segregation processes, and schema-based processes. Primitive processes are responsible for partitioning the music into high patterns and low patterns, and schema-based processes, are responsible for the selection of patterns within these parameters.

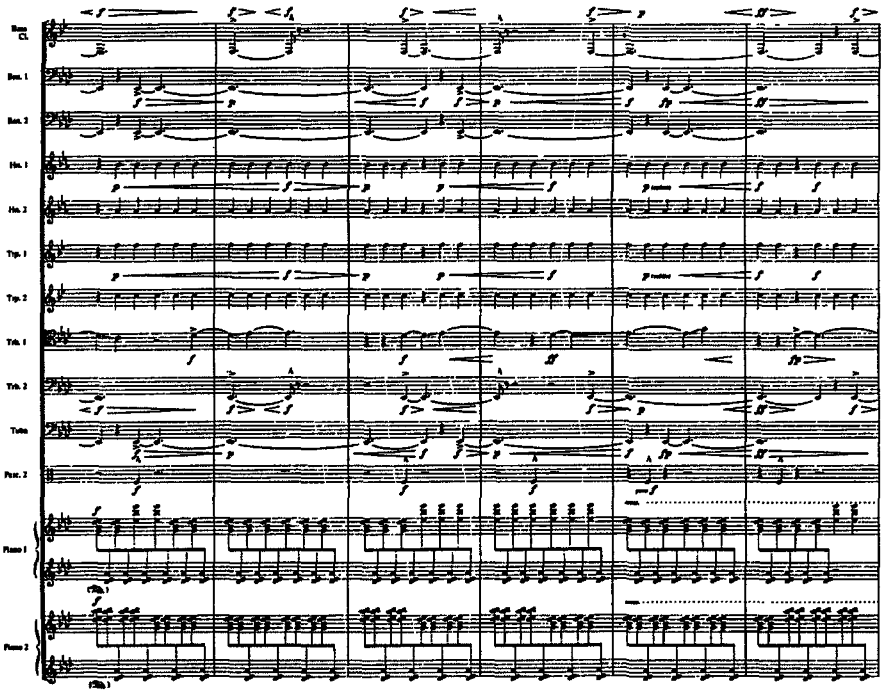
Schwarz (1993) explores what he calls "the middle-ground between pieces of music as texts and psychic structures upon which their perception depends" (p. 24). These structures include the "sonorous envelope" and the "acoustic mirror". By 'listening subject', Schwarz refers to "that which is neither exclusively text, nor listener, nor culture, but a product of all three" (p. 26). More specifically, "music listening subjects are produced when moments in performed music allow access to psychological events that are presymbolic - that is, before our mastery of language" (p. 24). The first half of his discussion applies the concept of listening subjects to the music of John Adams.

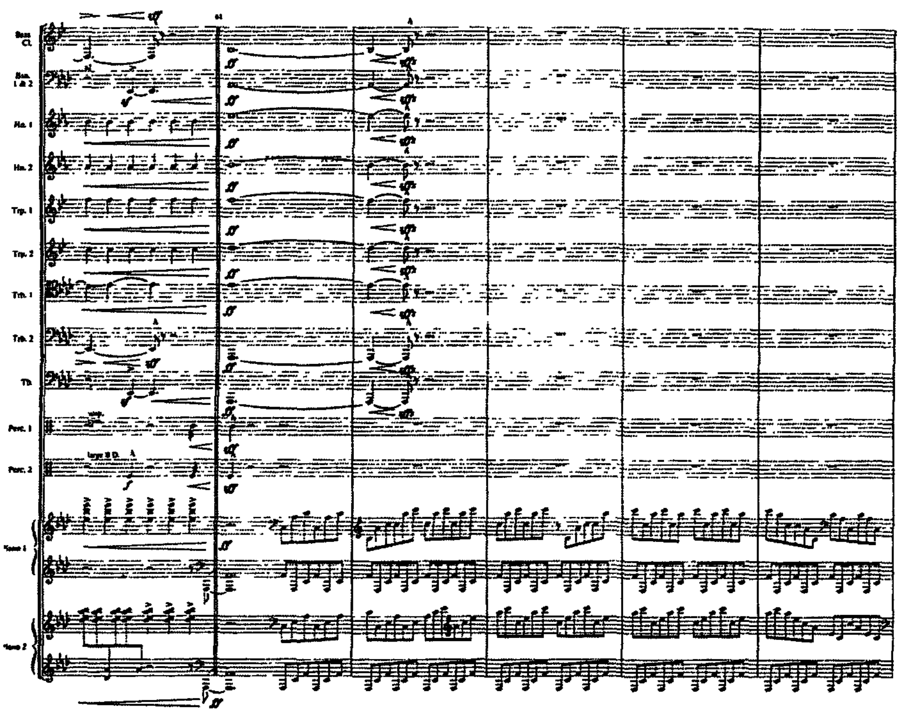
An excerpt from the third movement of *Grand Pianola Music* by John Adams is provided in Figure 2-11. The interlocking pianos, represented on the lowest two staves, are reminiscent of Reich's phase-shifting music in a number of ways. First, the notes in the remaining instrumental lines are derived from patterns within the interlocking piano parts. This is similar to the way Reich uses instrumental doubling to highlight patterns which are 'hidden' beneath the interlocking structure of *Violin Phase* and *Phase Patterns*. Second, like in Reich's phase-shifting pieces, the perceptual partitioning of the (piano) parts into registral streams is enhanced by the unanimity of the note qualities (that is, qualities such as dynamics and articulation). Despite showing signs of verticality, the use of crescendos, and other dynamic markings, as suggested by Schwarz, "produce an illusion of forward motion" (Schwarz, 1993, p. 40).

The difference between the use of interlocking patterns in this example (Figure 2-11) and Reich's phase-shifting music, is that in Reich's music, the interlocking structure often constitutes the essence of the composition, rather than providing a backdrop for other melodies with distinguishable timbres.

Figure 2-11 John Adams, *Grand Pianola Music*

Source: Schwarz, 1993, p. 41-42





Schwarz suggests that references to external sources may be experienced in *Grand Pianola Music.* He compares this with Reich's *Different Trains*, which "establishes the illusion of the sonorous envelope through a texture that suggests both an internal, oceanic immersion in repetitive fragments of sound, *and* an external, and iconic representation of trains" (p. 40). Reich's earlier work, by contrast, offers little external reference. Schwarz speaks of the "meaning-stripping function of repetition" in relation to the introduction of speech in *Different Trains* (p. 43). In particular, he refers to the clarity of speech, which becomes more and more distorted as the piece progresses.

The meaning-stripping function of repetition, in addition to tonal consistency, and lack of phrase structure and other temporal indicators, enhances the role of primitive (pre-attentive) perceptual processes in Reich's music. Schwarz reinforces this function in two of Reich's spoken tape loop pieces: *It's Gonna Rain* (1965) and *Come Out* (1966). He refers to Freud's essay, *The Uncanny,* when discussing the fading in and out of words and syllables in *It's Gonna Rain.* For example, he suggests that "the uncanny seems to emerge *out of what had been familiar*" (p. 44).[4] Schwarz describes the appearance of the word "go" (as a syllable of "gonna") as uncanny at the point when "go" detaches itself from its origin, and takes on a new meaning (p. 44).

In comparison with the music of John Adams, Schwarz views *Piano Phase* and *Violin Phase* as producing a different type of acoustic mirroring. He refers specifically to performances involving solo performer and pre-recorded tape. In relation to *Violin Phase*, he states:

> As the violinist moves out of phase with the tapes..., a space opens up in which the listener hears first an acoustic tugging, followed by echo effect, followed by clear out-of-phase voices. Psychoanalytically, this series of moments... renders how the fantasy of sonorous enclosure can only be heard in retrospect. That is, only after hearing voices split away from one another

[4] Emphasis in original.

> can we imagine their having once sounded together. (Schwarz, 1993, p. 46)

The image of the 'sonorous envelop', in Schwarz's view, is created when the listener hears intertwined and indistinguishable voices,

> *and* the fact that we know that one is stationary..., the other mobile and listening. Listening subjectivity is produced as the listener joins the configuration; he/she is stationary, like the taped voice, but while the tape is deaf (it can only speak), the listener is mute (we can only listen). (Schwarz, 1993, p. 46)

The cyclic unison, which begins all three of the instrumental phase shifting works, presents the listener with the impression of 'sonorous oneness'. As the two parts diverge:

> we hear a clear acoustic mirror as one voice literally echoes another. This initial unison-followed-by-divergence is heard as if from the listener's position, from within the imaginary order with its binary categories of listener, on the one hand, and immediate perception of sound, on the other. As the piece ends, however, we hear not a symbolic inscription of the imaginary into social space; rather, the fantasy simply reverses itself. (Schwarz, 1993, p. 46)

As suggested in Schwarz's discussion, and throughout the present chapter, the absence of referential meaning and symbolism in Reich's early music makes way for a different type of musical experience. That is, one in which the more traditional relationship between illusion, pattern, and 'meaningful' music is significantly altered; where nonlinearity prevails over linearity, despite the operation of a gradual process; and where attention is drawn to presymbolic concepts rather than symbolic ones. In "the process of gaining distance" from traditional temporality, the role of listening processes (and listening subjects) is heightened.

Summary

In Part One of the chapter, I introduced a paradigm for the study of musical time which encompasses four analytic perspectives: formal, analytical, experiential, and empirical. A multi-dimensional view of musical temporality was advocated for its ability to explore subtle relationships between linear and nonlinear elements of music. I argued that linear and nonlinear elements operate on different levels in Reich's music, and that the relationship between these levels can be exposed using a combination of objective and subjective approaches. The objective approach to temporality (formal/analytic), presented in Chapter 4 of the thesis, uses beat-class set theory to consider evidence of linear progressions in Reich's phase-shifting music. A subjective approach to temporality (empirical/experiential), presented in Chapters 5 and 6 of the thesis, involves a series of experiments designed to record listeners' perception of pulse, and the salience of resulting patterns in Reich's music.

In Part Two of the chapter, I suggested that Reich's phase-shifting music presents a system whereby musical sounds are essentially undifferentiated, and consequently, a range of patterns emerge from the musical texture with or without the listener's volition. For these reasons, I argued that Reich's phase-shifting music shares similarities with Derrida's notion of textual 'deconstruction'. For example, by removing a central bias, the listener is free to enter the 'play' of the musical system. Similarly, by minimising referential meaning and external symbolism we are left not with the question of 'what' the music means, but 'how' it means. This concept reinforces the importance of considering the processes which are responsible for the perception of resulting patterns.

Chapter 3

Auditory Stream Segregation: Review of the Literature

Structure of the Review

The literature review is intended to reflect the direction of the previous chapter, which considered both the nature of inflexible (unyielding) patterns, and the participation of repetitive patterns in the perception and experience of contemporary musical forms. In Chapter 2, I suggested that in simple repetitive patterns, the principles of organisation are the key to the nature of the design. In musical examples however, 'extra-auditory' factors must be taken into account, namely, culture, musical background, stylistic boundaries, and performance context. In Chapter 1, I addressed the fact that the complexity of music necessitates a re-evaluation of the potential application of perception research to examples from the musical repertoire.

I argue that approaches to methodology and analysis used to explore the role of stream segregation in music must be sensitive to the above factors. To what extent can existing methodologies, used to explore simple repetitive patterns, be transferred to the musical domain? This question is central to the evaluation of approaches and findings presented in the critique that follows.

The literature review is divided into three broad sections. The first section is intended to provide a survey of studies which reveal what we know about stream segregation, what factors are thought to influence the process of segregation, and the relationship between sequential and spectral organisation. The second section is devoted specifically to methodology. It is intended to reveal a wide range of possible approaches, and to assess the validity of each approach in relation to the present study. The third section of the review addresses conflicting theories about the role of primitive and schema-driven organisational processes, and critiques the limited number of studies which have attempted to apply the principles of stream segregation to musical examples. At the end of this chapter, the implications of cross-cultural studies on stream segregation are discussed.

Temporal Coherence and Fission Boundaries

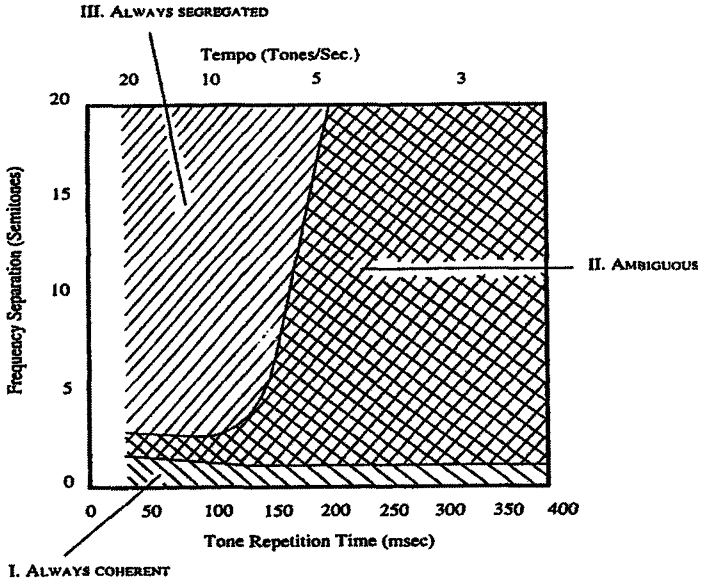
The majority of studies on auditory stream segregation (to be discussed below) have restricted their stimuli to simple repetitive patterns which have been created specifically to observe the nature of the process under strict laboratory conditions. These studies explore the boundaries of the process, by observing the strength of various conditions in terms of their ability to enhance or hinder segregation. In particular, the majority of early studies explored the influence of pitch proximity and pattern rate on the segregation of repetitive sequences.

In 1947, George A. Miller established that an alternating pattern of high and low tones presented at a fast tempo has the potential to split perceptually into two individual pitch sequences, one consisting purely of high tones and the other of low tones. In order to find out specifically how pitch distance participated in this phenomenon, Miller and George A. Heisse (1950) presented subjects with an alternating two-tone pitch sequence at a rate of five pitches per second. Listeners were required to manipulate the interval between a variable and a fixed tone, and to identify the point at which the coherent alternating pitch sequence split perceptually into a pattern of high tones, and a pattern of low tones. The boundary between the two percepts, coherent and segregated, was labeled by Miller and Heisse as the 'trill threshold'.

Leo van Noorden (1975) continued to explore the parameters of the trill threshold by manipulating both interval size and pattern rate. The parsing of an alternating pitch sequence into two or more streams was labeled "fission" (p. 2-3). Van Noorden's experiment revealed three perceptual regions which reflect the characteristics of auditory *coherence* and *fission* under varying conditions (see Figure 3-1). The narrow band that appears at the base of the graph (I) represents the condition under which an alternating two-tone sequence was found to be consistently coherent. That is, if the pitch distance between the two tones is approximately less than one semitone, then the auditory system is incapable of parsing the sequence into two discrete pitch levels. This was found to be the case independent of pattern rate.

Figure 3-1 Van Noorden's temporal coherence and fission boundaries (1975)

Source: Wegner, 1993, p.211.



The graph shows that tempo becomes influential for sequences containing pitch intervals greater than one semitone apart. The relatively large "ambiguous" region (II) to the right of the graph indicates the conditions under which sequences were susceptible to either coherence or segregation. Van Noorden contended that, in this region, the resulting percept depended on the "attentional set" of the listener. As seen in the graph, ambiguous percepts apply to tone sequences with pattern rates slower than 200 ms, and potentially maintain their ambiguity for a pitch interval distance of up to 20 semitones. Van Noorden's results show that when the interval size exceeded three semitones at fast tempos, the conditions secured a compulsory, "always segregated" response. Van Noorden's coherence and fission thresholds were obtained by averaging participants responses and, for this reason, should not be taken too literally. His findings, however, provided a strong platform for further questioning and experimentation.

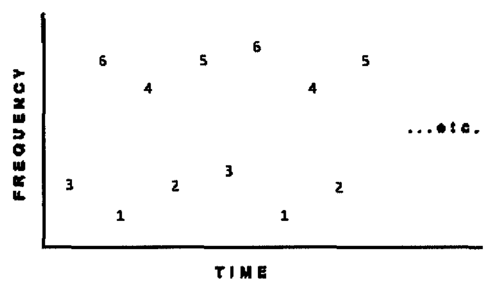
In an earlier paper, Albert Bregman and Jeffrey Campbell (1971) labeled the same phenomenon "auditory stream segregation". Bregman (1978b) later described the stream forming process as follows:

> If a sequence of tones of different pitches is played rapidly enough, it seems to split perceptually into two or more concurrent substreams. Subgroups of tones closely related in frequency, or following a smooth trajectory in frequency, will form part of the same stream. The splitting increases when the subgroups are farther away in frequency or when the sequence is played faster. (Bregman, 1978b, p. 380)

Bregman and Campbell (1971) conducted an experiment to observe how the stream segregation process affected listeners' ability to accurately judge the order of tones in cyclically repeating sequences. This research was guided by the assumption that temporal relations between streams are lost when stream segregation occurs. The researchers varied the order of three high tones and three low tones (see Figure 3-2), and listeners were asked to group the tones according to pitch streams. At slow tempos, subjects perceived the correct order of tones [1-4-2-5-3-6]. At faster rates, however, listeners heard two streams [1-2-3- and 4-5-6], and were unable to focus their attention on both streams at the same time.

Figure 3-2 Repeating cycle of six tones used by Bregman and Campbell (1971)

Source: Bregman, 1990, p. 17



At this point, a distinction can be made between those studies which examine the nature of the streaming process itself, and others which examine how stream segregation indirectly effects other perceptual capabilities such as judging the order of tones in a sequence. Although both kinds of studies are reported in this section of the review, the division of approaches into direct and indirect measures in the next section of the review aims to reinforce the objectives of each.

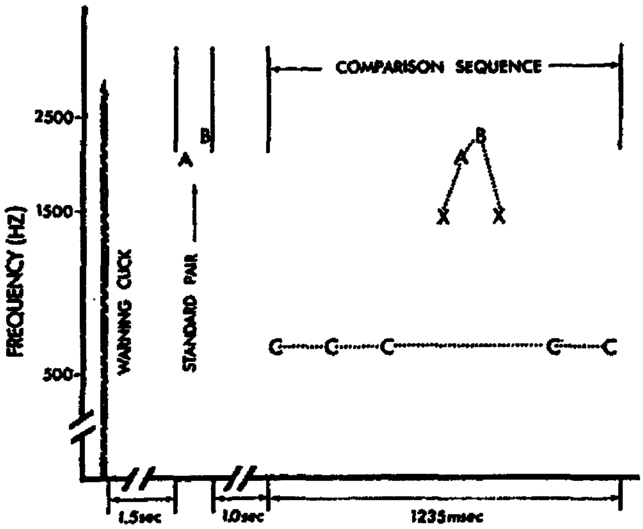
Once the basic conditions influencing stream segregation were revealed, researchers turned their attention to the relationship *between* auditory streams. The discussion of figure/ground reversal in the previous chapter questioned whether or not the visual object excluded from awareness was actually organised, or whether organisation was restricted to the object of attention. Similarly, a study conducted by Bregman and Alexander Rudnicky (1975) addressed the question of whether or not the 'unattended' stream in a segregated sequence is actually organised by the perceptual system as an entity.

Bregman and Campbell's study (1971) revealed that when stream segregation occurred, listeners were only able to attend to one stream at a time. The Bregman and Rudnicky (1975) experiment was designed to investigate whether or not this meant that "only one stream has been structured by processes of organisation" (p. 263). Their alternative hypothesis was that "a preliminary organizational process operates to decompose the input into several auditory streams and that a later process then allocates attention (pattern recognition process) to one of these streams" (p. 263). The subjects' task was to identify the order of a pair of tones, A and B. In isolation, listeners were able to correctly judge the order of two tones presented in rapid succession at very high presentation rates. In order to make the task more difficult, the authors introduced two additional tones (labeled x) of identical frequency which were presented at the beginning and end of the two tone pair (see Figure 3-3). Therefore, the onset and termination of the tone pair as an indication of temporal order was eliminated. The result was that the order of tones A and B became very difficult to judge. The objective of the experiment was to see if listeners' ability to judge the order of tones AB could be enhanced by introducing a captor stream which could strip the distractor tones (X's) from their original context. The interval distance between the distractor and captor tones was altered in three conditions. In the remaining condition, the captor tones were not present.

Figure 3-3 Stimuli used by Bregman and Rudnicky (1975)

Source: Bregman and Rudnicky, 1975, p.264

A and B = target tones, X = distractor tone, C = captor tone



The results of the experiment showed that listeners found the order of tones AB most difficult to judge when the captor tones were not present in the sequence, and when they were separated from the XABX pattern by a greater pitch distance. These conditions did not enable the target tones (X) to be captured out of the AB stream. The authors concluded that "whenever a sequence of tones forms a unified perceptual stream, it is both easy to select for pattern recognition purposes and easier to reject as a whole without its elements intruding on another concurrent stream which is being accepted" (Bregman & Rudnicky, 1975, p. 267). The authors' explanation for the effect was as follows:

> This latter effect arises from a "mutual exclusion" property of streams. When a sound is incorporated into one stream, it tends to be unavailable to a second stream. This is the property of "belongingness" referred to by Gestalt psychology: An element cannot be both a part of a figure and part of a ground at the same time. (Bregman & Rudnicky, 1975, p. 267)

According to Bregman and Rudnicky (1975), exclusive allocation in auditory streaming differs from the Gestalt principle of belongingness in vision, only in the sense that "ground is not really ground; it is unattended figures" (p. 267). A visual example which fits this description, however, was discussed in the previous chapter (Figure 2-5), in which the ground is best described as an unattended figure.

Sequential and Spectral Organisation

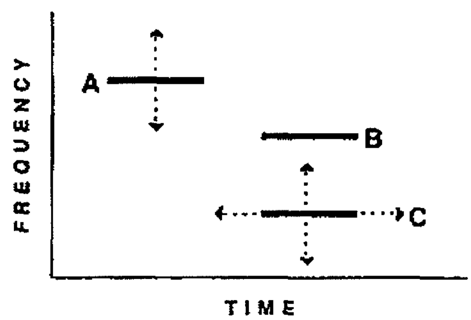
The majority of research presented in the literature has been concerned with the conditions necessary to separate a coherent *sequential* sequence into two or more auditory streams. Comparatively less research has examined the function of stream segregation in sequences containing *simultaneously* occurring sounds. Bregman (1990) questions whether or not the sequential grouping process that serves to decompose a complex spectrum (by capturing components out of it), is the same as the process responsible for the streaming phenomenon. However, he states that more research is needed to understand the relationship between the two kinds of sequential grouping.

An experiment conducted by Bregman and Pinker (1978) explored the relationship between sequential and simultaneous integration.

Figure 3-4 Stimulus used by Bregman and Pinker (1978)

Source: Bregman, 1990, p. 29

A, B, and C are pure tone components



The sounds used in the experiment were presented as a repeating cycle formed by the alternation of pure tone A with a "complex tone" consisting of two pure tone components B and C. Bregman (1990) describes this pattern as an "inherently ambiguous event" (p. 29). If the sequence was created by one person sounding tone

A, and another sounding the complex tone BC, the "correct perceptual analysis would be to hear a pure tone alternating with a rich-sounding complex tone" (p. 29). If, on the other hand, one person sounds an instrument twice on each cycle using tones A and B, and the other person plays tone C only once per cycle in conjunction with tone B, the listener should hear two auditory streams, one comprising the alternation of tones A and B, the other comprising only the repetitions of tone C. In this case, the listener will not perceive a complex tone BC, because "the richness is an accidental by-product of the mixture of the two signals" (p. 30).

The Bregman and Pinker (1978) experiment revealed that both types of organisation were possible, taking into account two factors: the frequency proximity of tones A and B, and the synchrony of tones B and C. When tones A and B were close together in frequency, this increased the probability that they would form a sequential stream. These findings suggested that the auditory system uses proximity as a clue to identifying common sources in both spectral organisation and sequential patterning.

As mentioned, the same experiment revealed the influence of 'synchrony' on the segregating potential of the sequence. If tones B and C were synchronised exactly, that is, their onsets and offsets were identical, the two tones tended to be heard as a complex tone BC. On the other hand, "if the synchrony of C and B was reduced, B would be more likely to group with A, unless... the AB connection was made weaker by moving A further away in frequency from B" (Bregman, 1990, p. 30). Bregman and Wright (1987) also acknowledge that the capacity for synchronicity to influence the segregation of a sequence is dependent on several other conditions such as pitch proximity, pattern rate, and the behaviour of neighbouring tones.

It should be pointed out that the organisation perceived by listeners in the Bregman and Pinker (1978) experiment was not restricted to either sequential or simultaneous grouping. Under certain conditions, listeners were able to direct their attention to either type of grouping. The authors do point out, however, that certain conditions made it more difficult for listeners to direct their attention in a particular way.

Factors Enhancing or Hindering Segregation

A substantial portion of research has been concerned with providing evidence for factors other than frequency-proximity and pattern rate that influence the formation of auditory streams. These factors include the cumulative effect, spatial location, continuity (frequency glides), trajectory, timbre, and loudness. Some of these factors have been examined specifically in relation to sequential patterns, and others in sequences containing a harmonic dimension.

The cumulative effect

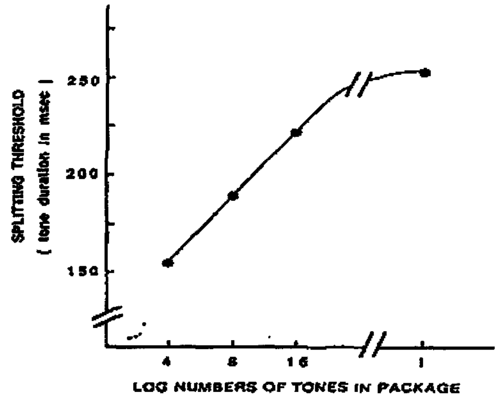
Several researchers have shown that the strength of stream segregation increases during the course of listening. That is, the longer a listener is exposed to a streaming sequence, the more difficulty they will have hearing the sequence as a single coherent stream.

Research into the "evidence-accumulating mechanism" (Bregman, 1978b, p. 381) was based on the observation that the process of decomposing an auditory sequence is sensitive to time. Bregman (1978b) conducted a series of experiments to show that stream segregation is not apparent at the onset of a series of sound events. In one experiment, pitch sequences of varying lengths, consisting of two high tones and one low tone (H1, L, H2, L, H1, L...), were followed by a four second silence before being repeated. The repetition of the sequence continued while the subject increased the pattern rate until the point at which segregation occurred. It was demonstrated that sequences with fewer tones between silences were not as susceptible to the evidence-accumulating mechanism as longer sequences (see Figure 3-5).

A second experiment (Bregman, 1978b) altered the length of the silence inserted between four-tone sequences of alternating high and low tones. It was demonstrated that the streaming effect was reduced by the length of the silences between sequences, that is, higher speeds were necessary to induce streaming when longer silences were embedded between sequences.

Figure 3-5 Cumulative effects in stream segregation, Bregman (1978b)

Source: Bregman, 1990, p. 129



A study by Anstis and Saida (1985) revealed compatible results. In an experiment, listeners were exposed to a continuous sequence consisting of the alternation of high and low tones over 30 seconds. Subjects responded by pressing one of two buttons to indicate whether they heard the sequence as coherent or segregated. Results showed that over time, listeners demonstrated a long-term trend toward hearing the sequence as segregated. This finding was attributed to "perceptual adaptation" (p. 258) which was viewed as causing a gradual decrease in coherence. Anstis and Saida emphasised that any model of auditory streaming must acknowledge the adaptation of the process over time. They suggest that "adaptation may reflect a progressive degradation of information about temporal order, and this loss of time information may alter the trade-off between proximity in time versus proximity in pitch, in favour of the latter" (p. 269).

Bregman (1978b) and Anstis and Saida (1985) provide different explanations for why the onset of stream segregation is time dependent. Bregman's "functional explanation" views the cumulative effect as "the way that the auditory system deals with evidence in a complex world" (Bregman, 1990, p. 130). He asserts that the conservative evidence-accumulating mechanism "prevents the system from oscillating wildly among perceptions of various numbers of streams in a complex environment" (p. 130). In contrast, Anstis and Saida's "physiological explanation" is that "segregation is not itself an active process which positively isolates streams but refers merely to a lack of links, so that adaptation in our experiment broke down the fusional links between tones of different frequencies, leaving intact the simpler fusional links between tones of the same frequency" (Anstis & Saida, 1985, p. 269).

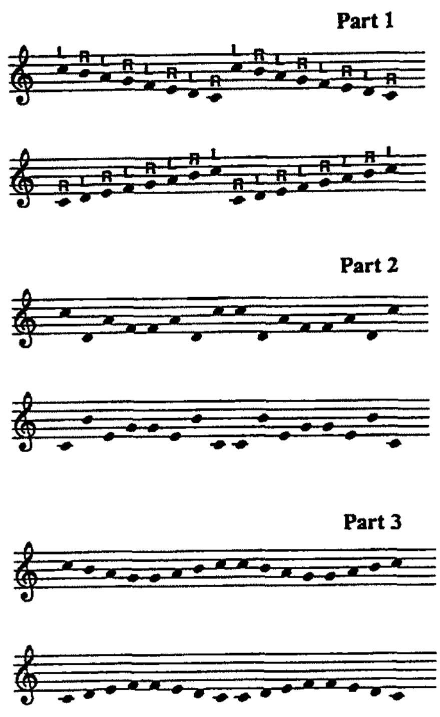
Spatial location

A number of studies have been carried out to examine how the sequential grouping of sounds is influenced by spatial separation. Van Noorden (1975) observed that the alternation of pitches in a sequence was not perceived when the two pitches were presented to different ears, and that the temporal relations between tones in opposite ears was weak. This observation however, was contradicted by the finding that other factors, such as frequency proximity, were capable of neutralising the effect (Deutch, 1975). Deutch's "scale illusion" demonstrated that listeners grouped tones by their frequency range rather than by spatial separation under certain conditions.

Figure 3-6 Deutch's scale illusion (1975)

Source: Bregman, *1990*, p. 77

Tones of the upper and lower staves in Part 1 were presented simultaneously. Part 2 represents what would have been heard if spatial separation dominated over pitch proximity. Part 3 shows what the majority of listeners perceived: tones grouped by frequency proximity.



The tones in the sequences presented by Deutch were 250 ms in duration. Bregman conducted a similar experiment using faster tone rates (up to 20 tones per second), to test whether or not the failure of subjects to group tones according to ear of arrival was because Deutch's presentation rate was too slow (distance between tones 250 ms).[5] Bregman's observations supported the dominance of frequency proximity over spatial separation (Bregman, 1990, p. 76). Bregman (1990) concluded that "location differences alone will not be powerful influences on grouping, but will have a powerful multiplying effect when they are consistent with other information such as frequency-based ones" (p. 83).

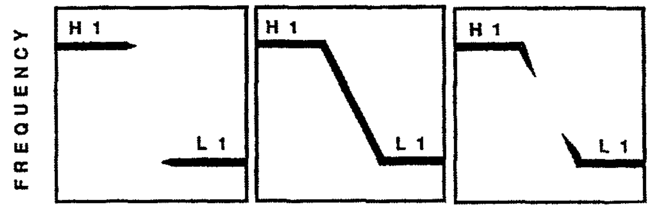
Continuity

Several studies have explored how the addition of frequency glides to notes in a pattern contributes to listeners' ability to form streams. This research is concerned with directionality, in the sense that frequency glides serve to promote the strength of pattern trajectories.

A study carried out by Bregman and Dannenbring (1973) explores this principle in relation to the coherence of auditory streams. The authors used cyclically repeating sequences of alternating high and low tones under three conditions (see Figure 3-7).

Figure 3-7 Three continuity conditions used by Bregman and Dannenbring (1973)

Source: Bregman, 1990, p. 135



Subjects were presented with two sequences, and were asked to judge if the order of tones were the same or different. The results revealed that the "discrete" condition

[5] Unpublished experiment reported in Bregman (1990)

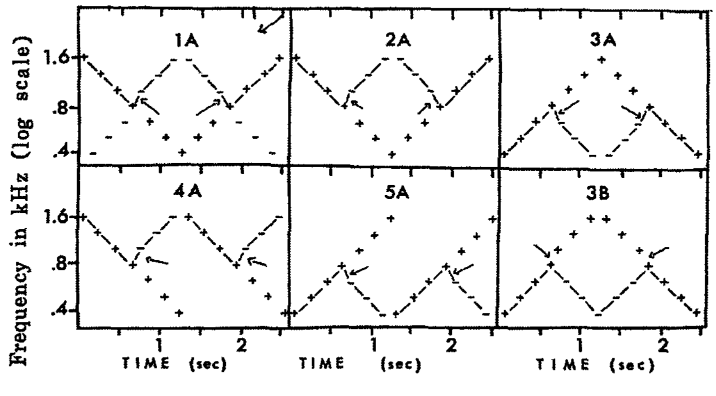
made it difficult for listeners to judge the order of tones correctly. The ability of listeners to judge the order of tones in the "ramped" condition, however, suggested that frequency glides increased the tendency for a sequence to be perceived as a single stream. Bregman and Dannenbring's initial interpretation of the data was that the semi-ramped condition was more coherent than the discrete condition because "the auditory system probably was able to use these brief glides to predict the frequency region of the next tone" (Bregman, 1990, p. 135).

Trajectories

The findings of a more recent study put the findings of Bregman and Dannenbring's (1973) study into question. Tougas and Bregman (1985) demonstrated that grouping tones by their frequency proximity dominated over grouping tones that followed a smooth trajectory.

Figure 3-8 Stimuli used by Tougas and Bregman (1985)

Source: Tougas and Bregman, 1985, p. 790



In this experiment, listeners were presented with a series of target and comparison patterns. Some target patterns were made up of the bouncing component of the patterns shown in Figure 3-8, while others comprised of the trajectory based component. Listeners were asked to rate the clarity of isolation of the target pattern when heard as part of the comparison (the complete pattern). Listeners' rating responses were taken as indicative of the strength of stream formation. That is, if stream segregation was strong, listeners' ability to follow the trajectory-based component of the patterns would be reflected by low ratings.

The results demonstrated that the trajectory-based target patterns were difficult to isolate as discrete perceptual units. This finding was attributed to the fact that these target patterns consisted of tones belonging to different streams. It appeared that the clarity of the frequency-based percept was marginally reduced in patterns 2 and 3. This finding was attributed to the irregularity of the rhythm in these examples, which was assumed to facilitate the isolation of the trajectory-based target patterns. Tougas and Bregman concluded that the "strong positive values obtained for the bouncing-superiority score indicated that the tendency for bouncing was markedly superior to that for crossing in all the present stimulus patterns regardless of rhythm" (Tougas & Bregman, 1985, p. 792). The implications of these findings will be discussed further in the section of the review that deals with primitive and schema-driven organisation.

Timbre

Smith, Hausfeld, Power and Gorta (1982) investigated the conditions under which timbre would counteract Deutch's musical scale illusion (discussed earlier in this section of the review, see Figure 3-6). The authors chose piano, ocarina, harpsichord, and saxophone sounds to encourage the coherence of tones grouped by ear of arrival. Tones in the left ear were presented using one setting, and tones in the right ear using another. The researchers demonstrated that their listeners were frequently able to avoid the illusory percept, and provide an accurate account of what was being presented in each ear. In another condition, a different timbre was assigned to ascending and descending scales, that is, the same timbre was alternating between the two ears. Once again, listeners were capable of resisting the bouncing percept (encouraged by frequency proximity) in favour of hearing the two streams crossing one another.

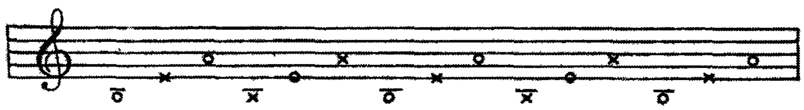
In an earlier study, McNally and Handel (1977) presented subjects with sequences consisting of combinations of pure tones. These included clicks of different spectral compositions, white noise, and a buzz. By arranging cards representing each of the component sounds, listeners were asked to indicate the order of presentation of sounds in each trial. The authors found that correct order judgements were made more often when sequences consisted of two identical consecutive sounds. These results and others (eg. Warren, Obusek, Ackroff and Warren, 1969) suggest that accurate judgements of order "require sounds to be in the same stream and that sounds with grossly different timbres resist being assigned to the same stream" (Bregman, 1990, p. 94). While these studies demonstrated the stream forming potential of sequences on the basis of timbre, they did not consider which components of timbre were responsible for the effect. This aspect was investigated by Wessel (1979) who manipulated the 'brightness' of tones in a cyclically repeated three note sequence, in which he defined the brightness of a sound as the concentration of partials in the spectrum.

Figure 3-9 Stimulus used by Wessel (1979)

Source: Bregman, 1990, p. 97

Effects of Spectral brightness on stream segregation

Note types (o and x) represent two different levels of brightness



For example, a tone with a higher level of brightness has more energy in the higher partials. As the difference in the brightness between the two tones was increased, the sequence was less likely to be heard as a repeating ascending three tone pattern, and more likely to be grouped according to brightness.

Loudness

There have been a number of studies which have investigated the contribution of loudness to sequential grouping. For example, van Noorden (1975) presented subjects with a sequence consisting of alternating soft and loud tones of the same frequency. When the difference in intensity of the two tones was between 3 and 40 dB, listeners could direct their attention to streams consisting of either all loud tones, or all soft tones. Van Noorden did not measure the effect of loudness when listeners were trying to hear the sequence as a coherent auditory stream, but rather, measured listeners' ability to selectively attend to either the loud or soft tones. This distinction is central to the discussion of primitive and schema-driven segregation to be discussed later in this review.

Summary and Evaluation

The studies reviewed above demonstrate consistency on a number of levels. The majority of studies manipulated short, repetitive sequences in order to observe the behaviour of segregation under different conditions. Most studies acknowledge the contribution of frequency-proximity to the formation of auditory streams, and recognise its correspondence with the principle of 'belongingness' in Gestalt psychology (Bregman & Campbell, 1971; Bregman & Rudnicky, 1975; Miller & Heisse, 1950; van Noorden, 1975). Additional studies recognised the capacity of frequency proximity to assist the decomposition of simultaneously occurring sound events (Bregman & Pinker, 1978; Bregman & Wright, 1987; Steiger & Bregman, 1985). Several of the studies mentioned above (Bregman & Campbell, 1971; Bregman & Rudnicky, 1975) revealed that when stream segregation occurred, listeners were only able to attend to one stream at a time; a finding which can be likened to the visual experience of figure/ground reversal, specifically, the type in which the ground has the capacity to act as a figure in its own right.

Other factors shown to either enhance or hinder the process of stream formation in the studies reviewed above were the cumulative effect (Anstis & Saida, 1985; Bregman, 1978b), spatial location (Bregman, 1990; Deutch, 1975; van Noorden, 1975), frequency glides (Bregman & Dannenbring, 1973), trajectory (Tougas & Bregman, 1985), timbre (McNally & Handel, 1977; Smith, Hausfeld, Power & Gorta, Wessel, 1979), and loudness (van Noorden, 1975). All of the studies mentioned above provide a solid foundation for exploration in a musical context. It is argued in this study, however, that in an attempt to contribute to music theory, applying these principles to musical examples should go beyond providing perceptual evidence for what musicians and composers already know intuitively. I propose that in musical compositions where inherent and perceived structures are largely compatible, little is gained by exploring the rules of stream segregation, except perhaps to 're-spell' the characteristics of stylistic practices in scientific terms. Rather, the present research uses the information provided by the studies reviewed in this chapter to explore musical examples in which the resulting patterns are deliberately ambiguous. The boundaries of coherence and fission are intended, in this study, to provide an insight into the extent to which listeners can shape their own experience of Reich's early works.

The characteristics of the streaming process, defined in the studies listed above, also allow for an investigation of the extent to which Reich maintains perceptual ambiguity in his later compositions. A wider 'spacing' of musical parameters (referring to pitch, spatial location, pattern rate, timbral difference etc.), as suggested by the review, leads to a more stable stream, avoiding regions promoting ambiguous percepts. It is argued that Reich's later works demonstrate a move towards 'freezing the play' of the musical system to a certain extent, that is, reaffirming the need for a stable centre.

Existing Methodologies

Introduction

Section two of the review focuses on the types of measures that have been employed by researchers to explore the factors that influence the segregation of streams, and the effects of stream segregation on the success of other tasks. This distinction is reflected in the organisation of this section into *direct* and *indirect* measures of stream segregation. The former are seen as obtaining a direct report of the experience of stream segregation. Indirect measures, on the other hand, obtain an index of stream formation through some other related phenomena. For example, the discrimination of temporal order is considered to be an indication of the strength of segregation. There has been some debate over whether indirect measures can be applied successfully to stream segregation, due to the fact that judgements such as temporal order may also be influenced by a range of additional factors. These issued will be highlighted throughout the following section of the review.

Stimuli

The majority of experiments cited in the literature used repeated sequences consisting of a limited number of sounds. Some of the reasons for this have already been suggested in Chapter 1 of the thesis, but will be considered further in the following discussion. Miller and Heisse (1950) and van Noorden (1975) used alternating two tone sequences to investigate the thresholds of coherence and fission. Other studies have used non-repetitive patterns consisting of three or more tones (Bregman & Campbell, 1971; Bregman & Rudnicky, 1975). Bregman outlines the benefits of recycled sequences for the study of stream segregation:

> ...it is a way of studying a temporal sequence of events that can be made very long (through repetition) while remaining the same in structure. It can retain the same types of relationships among its elements, and therefore be susceptible to a simple description, no matter how long the repetitions go on. This improves the chances that when we obtain an effect, we know what property of the stimulus has been responsible for it. (Bregman, 1990, p. 53)

The use of repeating sequences in experimentation has several other advantages. For example, the process of repetition minimises the contribution of starting and ending points to perceptual grouping. Anstis and Saida (1985), and Bregman (1978b) demonstrated that silent intervals of more than four seconds between sequences can 'reset' the perceptual mechanism, creating an initial bias toward coherence. Therefore, the use of repeating sequences in experimentation ensures that stream segregation has the opportunity to be fully realised. Another advantage of repetition is that "using a loop eliminates the use of certain slow cognitive strategies by the listener and increases the likelihood that basic processes of perceptual organisation are being studied" (Bregman, 1990, p. 53).

On the other hand, the use of repeating sequences potentially complicates the distinction between primitive and schema-based segregation. For example,

> despite the continuous wiping out of briefly persisting sensory memories, some knowledge about the sequence gradually accumulates and it becomes

> predictable. Therefore... the observed effects... may be influenced by this predictability as well as by the factors that are under study. (Bregman, 1990, p. 54)

Despite the diversity of stimulus types and approaches to the measurement of segregation identified in the literature, most studies have produced compatible results. As a precaution however, Bregman (1990) suggests that existing results must be considered as tentative until they are confirmed using alternate methods.

Direct Measures

The following survey of direct measures is based on the work of Bregman (1990). In this review however, each measure is discussed with reference to specific examples, so that the effectiveness of the various approaches can be considered in more detail.

Method of adjustment

Three important studies have sought to determine the average thresholds of stream segregation by asking listeners to manipulate a particular feature of the sequence presented, such as the pattern rate or distance between two pitches. The purpose of adjustment is to identify the point at which a sequence either segregates or merges into a coherent stream. One of the main problems associated with this method is that perceptual organisation has a "tendency to remain the same even after the sensory input changes" (Bregman, 1990, p. 55).

In the first study, Bregman (1978) used sequences consisting of two high tones and one low tone. The high tones differed in frequency (784 and 831 Hz) and alternated with the low tone (330 Hz) forming the pattern H1, L, H2, L, H1, L... etc. The number of tones presented between four second silences created the four conditions tested in the experiment: 0, 4, 8, and 16 second silences between tones in the 'package'. Patterns began at a slow rate (600 ms), "and the listener could turn a knob to speed it up until the point of splitting was determined. The subject then informed the experimenter who recorded the speed and began the next trial" (Bregman, 1978, p. 382).

Anstis and Saida (1985, Exp.2 & Exp.4) conducted another experiment designed to track the time decay of single-stream hearing. Using a potentiometer, subjects were asked to control the modulation rate (MR) of the stimulus tone which alternated between high and low frequencies (a major third, a perfect fifth, one octave, and one and a half octaves centred around a frequency of 1000 Hz). The initial modulation rate for each 60 second trial was arbitrarily set to 8 cycles per second. Subjects were instructed to reduce the MR when the frequency modulated tone seemed to break up into two segregated streams, adjusting the rate until the tone appeared to return to a single coherent stream. Subjects continued adjusting the modulation rate throughout the trial. Anstis and Saida's research showed that "as adaptation continued, the MR had to be reduced, first rapidly and then more slowly, in order to hold the stimulus at the perceptual borderline between segregation and coherence", and that "the probability of coherence decreased systematically as the tonal interval (the depth of FM) increased" (Anstis & Saida, 1985, p. 263).

Both the Bregman (1978) and Anstis and Saida (1985) studies used the method of adjustment to measure the cumulative effect (discussed in section one of the review). Steiger and Bregman (1982) however, used the method of adjustment in an experiment which was designed to explore the "ability of elements of a stream to resist becoming fused with other synchronous events, heard either in the same ear or at the opposite ear" (p. 153). Listeners were exposed to a sequence consisting of a 'target tone' and a 'captor tone'. Their task was to gradually increase the volume of an additional 'masking tone' until they became uncertain as to whether or not the target was still audible. This point was intended to reflect "the level at which the target and mask began to fuse into a single image" (p. 156).

Proportion of time integrated and segregated

Using this procedure, the listener is instructed to hold down one button when they perceive a sequence as integrated, and another button during periods they perceive it as segregated. Bregman (1990) believes that this type of measure is useful for sequences which have a tendency to oscillate between the two percepts. For example, Neff, Jesteadt, and Brown (1982: Exp.3) tested judgements of stream segregation for sequences that were "expected to vary in perceptual organisation" (p.

496). Listeners held down one button when they *could* perceive the sequence as a single coherent unit and the second button when the sequence broke apart into two or more perceptually discrete units.

Similarly, in order to demonstrate that faster tempos decrease the likelihood of coherence, Anstis and Saida (1985: Exp.1) instructed subjects to hold down one of two computer keys continuously over a 30 second listening period. One of the keys was to be pressed when the stimulus sounded like a single tone "jumping up and down in frequency (coherence)", and the other "when it sounded like two concurrent, interrupted tones (segregation)" (p. 259).

Rating scale for fixed presentations

Yet another method is to ask subjects to indicate the strength of segregation of a sequence by responding on a rating scale. It should be noted however that although this type of measure provides a direct account of the experience of stream segregation, results cannot be easily cross referenced with other experiments.

In order to establish whether listeners were hearing one or two auditory streams in a repetitive sequence, Bregman and Dannenbring (1973: Exp.2) instructed subjects to place a mark along a 100 mm continuum with the extremes "definitely one stream" and "definitely two streams". Using a slightly different method, Bregman (1978b: Exp.2) provided subjects with a choice of two boxes. "Yes" indicated that a target pair could be heard easily in a comparison sequence, and "no" indicated that the target could not be heard easily. Subjects were also asked to record the level of difficulty in making their choice, by responding on a seven-point rating scale which ranged from "very easy to decide" to "very hard to decide" (p. 395).

Drawing or writing down what you hear

The method of drawing or writing down what you hear is more appropriately used in experiments involving musically trained listeners. Subjects are given a set of cards, each card delineating a specific component sound, and instructed to arrange the cards according to what they hear. In a study conducted by Handel, Weaver, and Lawson (1983, Exp.1) subjects were asked to indicate how they perceived the grouping of tones in various sequences. Subjects responded by connecting elements that seemed to go together. For each sequence, the 'actual' order of elements was drawn on a piece of paper relative to pitch height, and subjects responded by drawing lines between elements which seemed to be grouped together (p. 642).

This method has often been used in association with temporal order judgement tasks, therefore, its categorisation as a direct or indirect measure is flexible depending on the nature of the task. Other studies associated with temporal order judgements are reported in the section concerning indirect measures.

Indirect measures

Pattern recognition

Research by Bregman and Rudnicky (1975) suggests that the recognition of patterns is significantly influenced by the streaming process. For example, if a pattern is formed from notes belonging to a single stream, it is recognised easily. On the other hand, if a pattern is formed from notes belonging to two or more different streams, recognition becomes increasingly difficult. Researchers have used pattern recognition tasks in order to investigate the extent to which stream segregation can reduce a listener's ability to identify patterns.

Dowling, Lung and Herrbold (1987) instructed subjects to listen for the presence of a *familiar* melody within a sequence. Distractor notes in the same pitch range and of the same timbre were interleaved with the familiar tune. The authors revealed that subjects' ability to perform the "hidden figures" task "depended on the rhythmic control of attention on the basis of expectancies developed through perceptual learning with melodies in the listeners' culture" (p. 642). Studies of this kind have revealed that listeners' familiarity with a tune enables them to attend to it despite the fact that distractor tones exist within the same pitch range. The results of Dowling, Lung and Herrbold's study raise the question of what conditions are necessary for schema-based organisation to override primitive processes of segregation. This discussion will be continued in the following section of the survey.

In a different kind of pattern recognition task, listeners have been presented with *unfamiliar* target patterns. The target pattern is presented in isolation, and then presented as part of a more complex pattern. The target pattern contains a sequence of tones that "would be isolated if the listener were organizing the test sequence in a particular way" (Bregman, 1990, p. 57). At the end of each trial pair, listeners are asked to indicate whether the target pattern could be heard in the comparison pattern, or alternatively, to rate the clarity of isolation of the target pattern on a rating scale. According to Bregman (1990), this method is valuable because the basis of the scene analysis process is isolating patterns from one another.

Most importantly, this method can be used to determine "which of several ways of hearing an ambiguous stimulus is stronger" (Bregman, 1990, p. 56-7). Tougas and Bregman (1985a: Exp.1 & Exp.2) investigated the ability of listeners to identify patterns which intersected auditory streams.[6] Listeners were asked to rate the clarity of isolation of the target patterns within the comparison patterns. The seven-point rating scale used in the experiment ranged from "very clearly not isolated" to "very clearly isolated." The former response was used to indicate that the target pattern could not be heard at all within the comparison pattern. Subjects were informed that the target pattern was always present in the comparison, "but that it would not always be heard as a part that was easy to isolate" (Tougas & Bregman, 1985, p. 791).

Rhythm changes

The 'unfamiliar' pattern recognition task, described above, can be used to determine which rhythm patterns are perceived in a sequence, and how their clarity changes as a result of the process of stream segregation. Research has suggested that when a coherent stream divides into two separate streams, the perceptual rhythm is heard only within streams. Van Noorden (1975) conducted an experiment which observed the ability of stream segregation to alter the subjects' perception of rhythmic grouping. The sequence used in the experiment consisted of an alternating two-tone pattern (VFV-VFV). "F" represents a tone of fixed frequency, and "V" a tone of variable frequency. The results showed that listeners perceived a galloping rhythm

[6] The stimulus patterns designed by the authors were included in section 1 of this review (Figure 3-8).

(VFV-VFV) when the sequence was heard as a single stream. When the frequency distance between V and F increased, listeners heard two evenly paced streams, one consisting only of tone V (V-V-V) and the other of tone F (F---F---F). Van Noorden used a variation on the method of adjustment (reported earlier in the direct measures section of the review) in association with the method discussed here. Rather than having listeners adjust the variable tone themselves, the pitch of the variable tone ascended and descended automatically over a period of 80 seconds.

Judgement of the order of elements in a repeating sequence

Studies by Bregman (1978b), Bregman and Dannenbring (1973), and Bregman and Rudnicky (1975) discussed earlier in the review, have all used temporal order judgement tasks to investigate different aspects of the streaming process. The assumption underlying all of these studies is that the segregation of streams makes the overall order of sequences difficult to judge. McNally and Handel (1977) have used this method to explore how stream segregation effected listeners' ability to place elements of a recycled pattern in the correct order. The sounds represented on each card were presented in isolation to familiarise subjects with the association. After each sequence, subjects arranged the cards in the perceived order. In a similar procedure, Handel, Weaver, and Lawson (1983: Exp.2) gave subjects four index cards, and asked them to arrange the cards to represent the order of events in the presentation sequences. Subjects chose one of three labels to represent the pitch height of the sounds: musical notation; numbers from one to four; or descriptive labels including low, low-middle, high-middle, and high.

Kathy Barz (1988) reported two conflicting hypotheses related to the temporal order of tones. Specifically, she explores the contradictions present in the results of studies by Warren (1974a, 1974b; Warren and Ackroff, 1976; Warren and Byrnes, 1975) and Bregman (1978; Bregman and Campbell, 1971; Bregman and Dannenbring, 1973). For example, Warren suggests that even when a sequence segregates, it "can be discriminated at better-than-chance levels on the basis of the order of the sounds" (p. 294). Bregman, on the other hand, states that the inability to judge temporal order is a direct effect of stream segregation. Barsz suggests several reasons why Warren and Bregman view the relationship between temporal order and stream segregation differently. The discrepancy is largely attributed to inconsistencies in methodology, including:

1. the nature of the statistical analysis used
2. the fact that the perceived organisation of the sequences is influenced by:
   (a) the tempo of the sequence,
   (b) the frequency relationships present among the sequential and simultaneous components of the sequence,
   (c) loudness variations among tones in the sequence,
   (d) the amount of time the subject listens to the sequence, and
   (e) whether the listener is trying to hear the sequence as segregated or integrated.

Barsz concludes that there is little data to support the hypothesis that temporal order recognition performance is actually related to perceived organisation. For this reason, the temporal order judgement is not considered a reliable measure for examining perceptual organisation in musical examples in this study.

Counting tones

Another method of measuring stream segregation involves counting the number of tones in a sequence. This method has only been used in one study by Massaro (1977). The assumption is that when stream segregation occurs, listeners will have difficulty accurately reporting the number of tones in a pattern. However, this method shares problems with those mentioned above, because the ability to count tones may be affected by variables other than stream segregation.

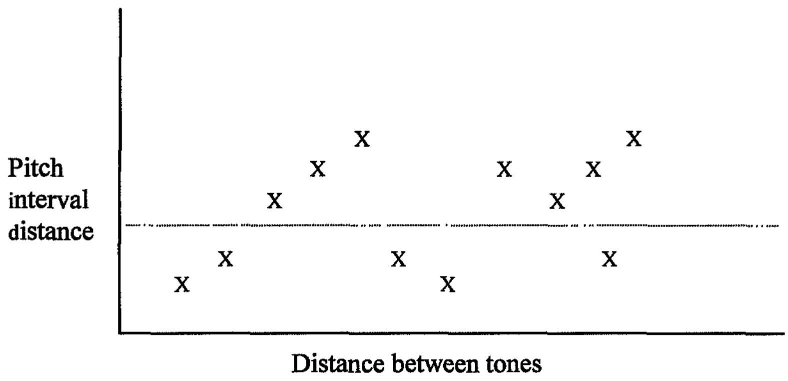
Evaluation of Measures

The application of stream segregation principles to examples of repetitive music are supported by several comments made early in this section. In particular, repetitive patterns, and consequently repetitive musical patterns, allow an investigation of the temporal order of events in an unchanging context. In addition, repetitive sequences ensure that the cumulative effect has time to register. These points, however, do not suggest that the methods outlined in this section of the review can be applied directly to repetitive musical examples. Even in simple musical sequences, the increase in the number of tones (level of complexity) means that many of the methods described here are inappropriate. For this reason, it important to justify which of these methods are suitable for investigating the role of stream segregation in the perception and cognition of Reich's phase-shifting music.

The approaches to methodology outlined in this section were divided into direct and indirect measures. Direct measures included: adjusting some feature of the stimulus; measuring the proportion of time integrated or segregated; using a rating scale for fixed presentations; and drawing or writing down the perceived organisation. These measures have been shown to be appropriate for the measurement of stream segregation in simple two or three tone sequences. The measures described would also be suitable for more complicated sequential sequences, such as the principle pattern in Reich's *Piano Phase*.

Figure 3-10 Graphic representation of the principal pattern in *Piano Phase*

The dotted line indicates the point at which streaming is likely to occur, that is, the widest interval distance (a fourth) between consecutive tones in the pattern.

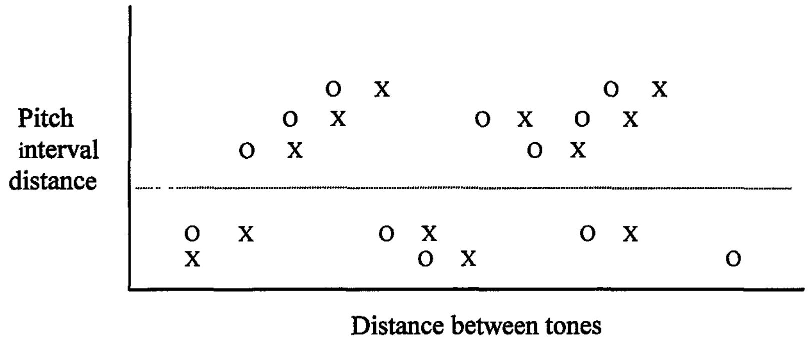


The method of adjustment could be used to measure the point at which listeners can no longer hear the above sequence as coherent (temporal coherence boundary), that is, by adjusting pattern rate, or the distance between high and low pitches. However, with sequences consisting of simultaneous tones, the point at which the sequence segregates is imprecise.

Figure 3-11 Graphic representation of phase 1 in *Piano Phase*

"x" indicates notes played by player one.

"o" indicates notes played by player two.



Due to the number of notes in both the (potential) high and low streams, the point at which the high tones separate from the low tones will not be measured as successfully as in two-tone sequences. Figure 3-11 also demonstrates the inappropriateness of the measure which requires subjects to draw or write down the perceived grouping of tones. In fast sequences, the task would be extremely difficult and highly unreliable.

Measuring the proportion of time integrated or segregated has been shown to be suitable for sequences which are likely to oscillate exclusively between one percept and another. This measure, however, is not as suitable for sequences of tones which fall into van Noorden's "ambiguous" region (see Figure 3-1), where the alternation of the percept depends on attention. Similarly, rating the level of segregation, or stating how many streams are present within a sequence, would be a vague measure in more complicated 'musical' sequences. This is true particularly for sequences containing simultaneously occurring sounds (as in Figure 3-11), where many pattern configurations are possible.

Another argument concerning the application of direct measures to musical examples is that the task required by the subject is incompatible with music listening in general. The same applies with indirect measures, that is, judging the order of elements, or counting the number of tones in a sequence. By comparison, recognising patterns, or detecting rhythm changes, are much less foreign to the experience of music listening. As mentioned above, some of the approaches used in experimentation are more useful for measuring stream segregation under extreme conditions. Due to the fact that the conditions required to incite 'compulsory' segregation (the temporal coherence boundary) are very rare in musical examples from the existing repertoire, it seems more appropriate to use a method designed to determine "which of several ways of hearing an ambiguous stimulus is stronger" (Bregman, 1990, p. 57). The pattern recognition method is considered to be the most effective way to obtain such information. The reasoning is that when stream segregation is active in a musical sequence, patterns intersecting auditory streams (that is, pattern containing notes from different streams) will be difficult to hear.

Primitive Auditory Scene Analysis vs. Schema-Based Scene Analysis

The following section of the review discusses studies concerned with distinguishing between primitive auditory segregation and schema-based segregation. This distinction was first recognised by van Noorden (1975) who revealed that thresholds for coherence and fission depended on what the subject was asked to listen for within a sequence. The point at which listeners heard a single stream split perceptually into two separate streams was labeled the "temporal coherence boundary", while the point at which a listener could no longer hear a sequence as segregated was defined as the "fission boundary" (see Figure 3-1). Van Noorden found that it was much easier for subjects to hear the alternating two-tone sequence as segregated than it was to hear it as a single coherent stream under the same conditions. Bregman (1990) suggests that listeners' ability to maintain a segregated sequence can be explained by storing "a mental description of the sound and its periodicity and try[ing] to match the stored description to the sequence" (Bregman, 1990, p. 406).

Central to the distinction between primitive and schema-based segregation was van Noorden's finding that *only* the "temporal coherence boundary" was influenced by pattern rate. This suggests that van Noorden was measuring the thresholds of two different perceptual processes. Definitions of primitive and schema-based processes of organisation in the literature are outlined below to provide a foundation for their exploration in the context of Reich's music.

Definitions

Despite the conscious intentions of the listeners in van Noorden's experiment to organise their attention in a particular way, they were unable to parse an auditory sequence into a coherent sequence under extreme conditions. This suggests the presence of some primitive, automatic process of organisation. The use of the word primitive is intended to suggest that "the process is simpler, probably innate, and driven by the incoming acoustic data" (Bregman, 1990, p. 397). This can be contrasted with the fission boundary which "measure[d] the limits of an attention-based process in creating a stream by a process of selection" (Bregman, 1990, p. 407).

The argument for primitive segregation stems from the fact that our environment displays constant properties which would have to be processed by all human beings. Gestalt psychologists argued that the principles of perceptual grouping were innate. There is a significant amount of empirical evidence in the field of visual perception to suggest the existence of innate forces on perceptual organisation in infants (Bregman, 1990). Similar experiments related to auditory organisation, however, are few. One exception is a study conducted by Demany (1982) which demonstrated that infants were receptive to stream segregation.

The word schema is used by cognitive psychologists to refer to "some control system in the human brain that is sensitive to some frequently occurring pattern" (Bregman, 1990, p. 401). Therefore, a schema-based process "is presumed to involve the activation of stored knowledge of familiar patterns or schemas in the acoustic environment..." (p. 397). The difference between schema-based and primitive processes, is that primitive segregation is assumed not to utilise prior learning or voluntary attention. Although voluntary attention and prior learning are used in listening in different ways, they are grouped so as to be distinguished specifically from the primitive mechanism. Voluntary attention has been described by Bregman (1990) as "programmed attention, or attention that is under the control of an inner process that is trying to find some particular pattern in our sensory input" (p. 398). The role of learning in schema-based organisation can be clarified as follows:

> [Learning]...is based on the encounter of individuals with certain lawful patterns of their environments, speech and music being but two examples. Since different environments contain different language, musics, speakers..., the schema-based segregation skills of different individuals will come to have strong differences, although they may have certain things in common. (Bregman, 1990, p. 43)

Many of the studies discussed so far in the present chapter claimed to be measuring primitive processes of segregation. The methods they used to do this however, often involved the conscious effort of the subject to hear the sequence in a particular way. The role of attention in these studies makes it difficult to know which process has been affected by the conditions of the experiment. This concern is expressed by Bregman (1990) who acknowledges that it is difficult to know whether "to attribute the result of an experiment to attentional processes or to primitive processes that act independently of attention…" (p. 399). One solution is that if a task is made possible by trying harder, then the improvement can be attributed to attention (Bregman, 1990). Another way of testing for the presence of attention is through the knowledge that we have a more detailed awareness of things that are in our field of attention than things that are not. For example, as we become more efficient at a task through repeated application and practice, less attention is required to perform the task (Bregman, 1990). This point has been demonstrated by a series of experiments conducted by Jay Dowling (1973a, 1987) who investigated the role of learning in the perceptual organisation of sound. Dowling's findings demonstrated that listeners were better at segregating a familiar tune from interfering sounds than an unfamiliar one (Dowling, 1973). The implications of Dowling's research are discussed further below.

Effects on stream segregation

Bregman (1990) suggests that if schema-based segregation is responsible for improving our ability to extract patterns from mixtures, then it might be asked why primitive processes are necessary at all. His explanation is that:

> ...schemas can only do the scene-analysis job on familiar patterns. Yet if we are to learn about patterns in the first place, so as to make them familiar by forming schemas for them, we need some primitive processes that are capable of extracting them from their acoustic contexts. Although the primitive processes probably always make a useful contribution to scene analysis, it is in the realm of unfamiliar patterns that they are absolutely essential. (Bregman, 1990, p. 401)

Dowling's experiments investigated the difference between primitive and schema-based segregation, the results of which support an argument for their distinction. Two types of experiments involving the segregation of interleaved melodies were carried out. In the first type of experiment, Dowling studied listeners' ability to segregate a familiar arbitrary sequence from the same sequence mixed with another sequence of tones. As stated above, listeners were able to identify a familiar pattern more easily than an unfamiliar one. In another experiment, he familiarised listeners with a 'background' sequence (the distractor tones) prior to the task. The background sequence was interleaved with another sequence, and he asked listeners which of two possible sequences the new one had been. His findings confirmed that familiarity of the background melody did not assist listeners in isolating the target melody (Dowling, 1973). This finding has led Bregman (1990) to conclude that in pattern recognition, a "schema helps only if it contains either the target pattern itself, or both the target and background sounds" (Bregman, 1990, p. 408).

Based on this evidence, Bregman (1990) concluded that "the role of the primitive segregation processes is to *partition* the input, while the job of the schema-governed process is to *select* an array of data that meets certain criteria" (p. 408). This resolution has been challenged by Mari Riess Jones and colleagues (Jones, 1976; 1978; Jones, Boltz, and Kidd, 1982; Jones, Kidd and Wetzel, 1981) who advocate that stream segregation is based on an attention-based process which makes predictions about future events in an auditory sequence.

Jones's rhythmic theory of attention

Jones (1981) has studied the role of schemas on the perceptual organisation of sounds. Her research was based on a series of experiments involving the memory and recognition of short melodies and rhythms. Jones' results suggested that attention can be organised in a rhythmic manner. This means that when we listen to a pattern of sounds, the attentional process is capable of anticipating the position of the following sound on the time dimension. Importantly, predictable sequences allow their components to be caught in the net of attention, while unexpected elements may be lost (Bregman, 1990).

Jones's rhythmic theory of attention proclaims that auditory streaming results from an extension of the process of attention. Bregman (1990), on the other hand, prefers to separate schema-based attentional processes from primitive processes of organisation. Bregman (1990) views Jones' theory as defining a schema-governed process only, and criticises her approach by highlighting the problem of measuring perceptual integration using memory tasks, where listeners are asked to write down what they have heard, or to compare consecutive sequences. For Bregman (1990), one of the ways of minimising the contribution of memory is to allow listeners to respond to a stimulus while it is still present, by making the judgement task as simple as possible, or by using a measure other than the description of the pattern.

Bregman (1990) argues that Jones' rhythmic theory of attention is more applicable to the types of patterns found in tonal music, where hierarchies are formed out of distinct tones rather than irregular patterns found in the environment. In addition, her theory relates to sequential patterning, but does not account for spectral organisation.

In contrast to Bregman, Jones's theory assumes that the primitive process is not responsible for the organisation of an auditory sequence into streams. Rather, her theory is based on rules predicting the direction of the sequence. This implies that: learning will affect stream segregation; regular patterns will form more coherent streams; and streams are created by attention and the search for regular patterns.

Bregman (1990) disputes Jones' argument by suggesting that if the perceptual integration of a series of tones was based on the capacity of the attentional process to predict the position of the next tone, then her theory assumes that *randomly* ordered sequences of tones would not form coherent streams.

Although Bregman and Jones dominate the literature on the distinction between primitive and schema-based segregation, in particular the role of trajectories in the formation of streams, several other studies acknowledge the difference between active and passive listening. For example, Anstis and Saida (1985) point out that "sounds are not just passively registered but are actively organised perceptually, and we can catch our auditory system at work by listening to ambiguous stimuli that are interpreted first in one way then in another" (p. 257). Bregman and Wright (1987) also make a distinction between primitive and schema-based organisation. The authors argue that:

> the principles of auditory stream segregation operate on a content-free basis, that they provide the initial organisation upon which particular forms of learning, such as the learning necessary to comprehend musical or linguistic syntax, can take place. There can be no doubt that musicians go beyond this organization and use musical-specific rules to form a mental representation of the music, but it is likely that the preliminary content-free principles of grouping remain powerful determinants of the patterning of the music even for the sophisticated listener. (Bregman & Wright, 1987, p. 74)

This comment provokes a number of questions which are relevant to the next section of the review. At present, very few studies have considered the differences between musicians and non-musicians in terms of their ability to override the so-called primitive processes of organisation. Chapter 6 of the thesis reports two experiments which test the influence of musical experience on listeners' ability to segregate resulting patterns from Reich's *Piano Phase.*

Application to Musical Examples

As stated in the introduction to this review, the majority of studies on stream segregation have explored its role by manipulating simple auditory sequences, many of which contain no more than two or three notes in a repeating pattern. Only a handful of researchers have attempted to apply the principles of stream segregation to examples from the existing musical repertoire. There are two possible explanations for such an attempt. The first would be to see if the rules of segregation hold true for musical examples, that is, more complex forms of audition outside the laboratory. Although Bregman and Wright (1987) refer to auditory stream segregation as a "psychoacoustic theory", they claim that it "brings a set of vital new concepts to music theory" (p. 63). Specifically, they attempt to clarify how the streaming phenomena can "inform our understanding of the patterns of polyphonic music" (p. 63). The question raised here is can streaming theory tell music theorists anything about polyphonic music that they don't already know?

The main focus of Bregman and Wright's (1987) research was to consider how contrapuntal patterns can be manipulated, according to the principles of auditory stream segregation, to control the perception of harmonic dissonance. The authors claim that "in addition to raising some new questions about the psychoacoustic definition of dissonance, this approach demystifies certain well-established principles of traditional music theory and provides new ways to explain contrapuntal phenomena" (p. 63). This last comment partially answers the question raised above. That is, studies of this type may be limited to providing alternative ways to explain existing knowledge.

A second, and more informative reason for applying streaming theory to examples from the music repertoire, would be to reveal something about the musical experience that can not be obtained by formal musical analysis. The studies reviewed below investigate the role of stream segregation in two very different types of music. The distinction between linear, and non-linear music, as discussed in detail in the previous chapter, become important here. I argue that studies which apply the rules of segregation to more traditional 'linear' forms of music will not necessarily reveal anything about the music which is not already known intuitively by musicians and composers. By applying the same rules to certain non-linear repetitive forms of music however, we are able to predict and explore levels of ambiguity in musical pattern perception, these levels of ambiguity having a significant bearing on the resulting musical experience.

David Huron has considered the role of auditory stream segregation in the music of J.S.Bach. Huron (1989a) measured the "mean reaction time" of listeners to identify voice entries in 75 fugues. His findings led to the suggestion that "entries of inner voices were significantly more difficult to identify than entries of outer voices" (p. 43). In a follow-up study, Huron and Fantini (1989), questioned whether or not the difficulty of identifying inner voice entries "plays any role in the construction or organization of musical works. That is, do composers (consciously or unconsciously) compose their works in a manner that minimises the perceptual difficulty of hearing inner-voice entries?" (p. 44).

After identifying and analysing inner and outer voice entries in the same 75 fugues by J.S.Bach, Huron and Fantini (1989) concluded that "Bach neither favours nor avoids inner-voice entries in three- and four-voice textures. However, in the case of five-voice textures, Bach does show a significant reluctance to have a new voice enter in an inner voice position" (p. 46). This concurs with Huron's (1989a) hypothesis that "Bach endeavours to minimise perceptual confusion in his polyphonic works" (p. 47). He concludes that the data suggests that "the strategy to avoid inner-voice-engendered perceptual confusion may be necessary only in the denser textures" (p. 47).

These studies are concerned with the extent of the scene-analysis problem in multi-voiced music at the compositional level. However, the authors do not refer to specific studies of stream segregation in order to predict the perceived clarity of inner and outer voices. There is no mention of other musical parameters and devices which may either enhance or hinder the segregating potential of melodic lines. The conclusions were based on counting the number of entries in each voice rather than testing for their perceived clarity. Therefore, conclusions were not based on performance sensitive factors. It would perhaps be useful to clarify the conclusion that "Bach endeavours to minimise perceptual confusion in his polyphonic works" (Huron, 1989a, p. 47) by exploring the relationship between compositional 'conservatism' and performance practice. For example, the fact that performers of this music necessarily highlight voice entries so that they can be heard in the midst of polyphonic activity, may have minimised the need for concern on the compositional level.

In another study, Huron (1991) analysed 105 polyphonic works by J.S.Bach to demonstrate a reluctance for the crossing of voices. He concedes that "when the textural density increases beyond two concurrent voices, Bach becomes more vigilant to avoid part-crossing even though an increase in part-crossing is preordained" (p. 93), and equates this with evidence that "perceptual confusion increases with the number of concurrent voices" (p. 93). Huron concludes that his results show a significant agreement between the compositional practice of polyphonic music and experimental research concerning the segregation of auditory streams. Once again, however, listeners' perception of voice entries were not used to verify the fact that perceptual confusion increases with the number of simultaneous voices. It is argued that in musical examples, this conclusion needs to be tested perceptually, and weighed up against both internal musical relationships, and the characteristics of performance practice. Huron states that Bach's work is an appropriate medium for considering the role of auditory segregation, because "polyphonic composers explicitly construct multiple concurrent musical parts or streams whose perceptual independence is deemed important" (p. 95). This being the case, it is no surprise that an avoidance of inner-part entries and part crossing were identified in this music.

The final study reviewed in this chapter addresses the role of auditory stream segregation in the perception of "inherent patterns" in Bugandan xylophone music. The notion of inherent pattern perception was first described by Gerhard Kubik in 1960. Recent research in auditory perception and cognitive psychology however, has led Wegner (1993) to re-examine Kubik's theory about inherent patterns from a different perspective. Relevant features of Kubik's and Wegner's research are discussed below.

Wegner (1993) suggests that:

> what might be expected from a stronger mutual reference of ethnomusicology and cognitive psychology is an intensified research in music conceptualisations which are communicated by sound. Compared with research on music-related concepts as expressed in "speech about music" (terminology, classification systems, and so on) and as revealed by semantic analysis, those purely musical concepts as expressed in sound and their perceptual implications have been far less investigated. (Wegner, 1993, p. 201)

The objective of Wegner's study is to explore the cognitive strategies that form the perception of Kiganda xylophone music. Kubik based his ideas about the inherent patterns in *amadinda* and *akadinda* xylophone music of Buganda "on his observation of the incongruity of the sensory input as produced by xylophone players in Buganda and the listener's percept" (Wegner, 1993, p. 203). This "incongruity" has been found to be relevant to a wide range of East and Central African musics.

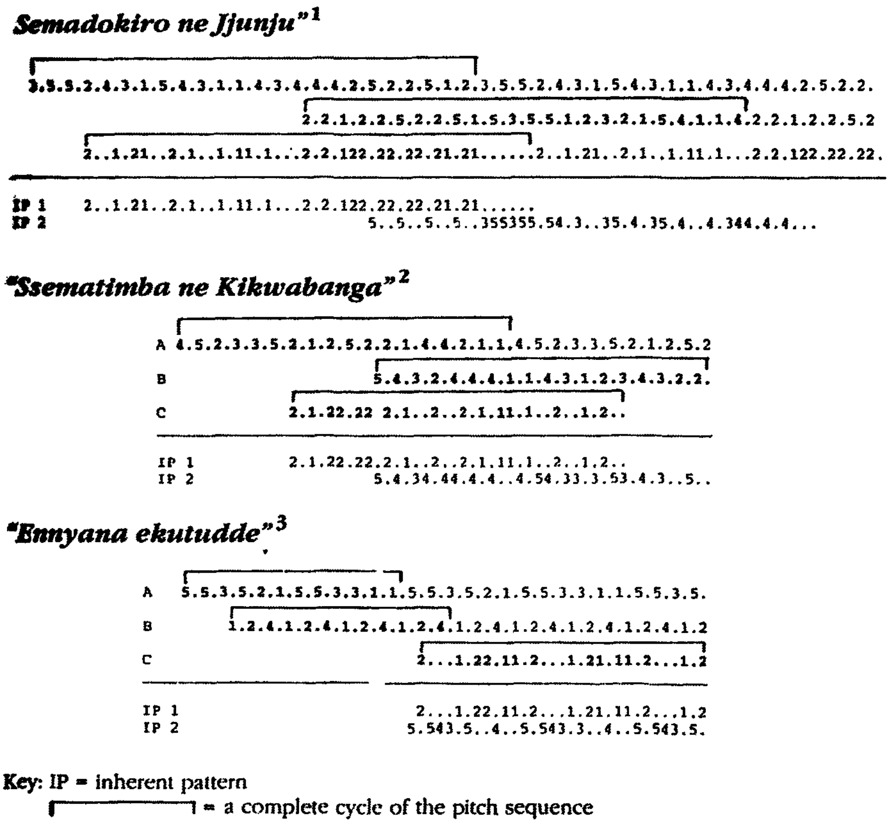
The two basic playing parts in Amadinda xylophone music comprise two interlocked pulse trains (the okunaga and okwawula). Kubik attributes the perceived patterns to the fact that the "auditory system is prevented from perceiving the resulting pulse train as a coherent melodic shape" (Wegner, 1993, p. 203). The fact that "pitches belonging to a pitch stream of two or three *neighbouring* pitches are now perceived as one coherent melodic unit" (p. 203), has been described as a restructuring of the perceptual input. The research surveyed throughout the present chapter clearly points to the process of stream segregation as a key to this "restructuring".

In reference to Figure 3-12, Wegner (1993) states that the "pitches 1 and 2 and pitches 3, 4, and 5 are coupled in an inherent pattern" (p. 203). The dynamic nature of the patterns results in a series of alternating percepts. That is, the listener usually perceives two contrasting two-note patterns, "plus one more ambivalent line" (p. 204). Kubik explains that the "ambivalent" notes, are capable of being assimilated into either the higher or lower pattern, and that patterns consist of a minimum of two tones or a maximum of three tones.

The parallels between the perception of patterns in this music and Reich's phase-shifting music are clearly evident. For example, *Piano Phase* (1967) also consists of 5 pitches arranged in a cyclic pattern, where the most significant pitch class sets comprise of a high pattern of three tones and a low pattern of two tones, although the intermediate tone "B" may be captured by either stream. The "inherent" or resulting patterns in *Piano Phase* and Reich's other instrumental phase-shifting works are also shaped by the characteristics of two interlocking voices of homogeneous timbre.

Figure 3-12 Inherent patterns in *amandinda* xylophone music

Source: Wegner, 1993, p. 203



Kubik identified a number of musical conditions which he believed to be essential for the emergence of inherent patterns. These conditions include the presence of an interlocking pattern, a fast tempo, cyclic repetition, metrically unaccented playing, and a "melo-rhythmic organisation within a frequency region having Gestalt like characteristics" (Wegner, 1993, p. 204). These points reflect Kubik's awareness of the grouping principles of Gestalt psychology. Perhaps more importantly, he acknowledges that inherent patterns are not accidental percepts caused by insufficient human auditory perception, but rather they represent the objectives of the compositional process. His comment that inherent patterns are "what many African composers are after by passion" (Kubik, 1960, p. 13), reinforces the distinction between this music, and music in which the intention is to clearly define melodic lines, so that perceptual grouping is largely predetermined.

The notion of inherent patterns in Amadinda xylophone music raises questions regarding whether or not listeners outside Kiganda culture would hear the same "inherent" patterns. In a number of studies, Kubik stated that the perception of inherent patterns is not a cultural trait, but rather a universal trait of the human perceptual apparatus (see for example, Kubik, 1979, 1983c, 1984). When we consider this comment in light of the distinction between primitive and schema-based processes of segregation, it would seem that Kubik is suggesting that a primitive, innate process of organisation is purely responsible for inherent pattern perception; that is, a process which serves to partition an auditory sequence into separate streams. I do not think that Kubik is denying the influence of schema-based influences in his comment that the perception of inherent patterns is "not a cultural trait", but rather suggesting that the patterns available for "attention" (potential patterns) are defined by a primitive process of segregation. A further comment, that "patterns obtrude themselves upon the listener regardless of cultural background", also suggests that partitioning takes place on a pre-attentive level (Kubik, 1979, p. 237). The suggestion that the capability of perceiving inherent patterns is a universal trait is contradicted however, in a further comment that the only prerequisite for hearing inherent patterns is "an at least average receptivity for music" (Kubik, 1979, p. 237). By suggesting a difference between receptive and non-receptive listeners in the perception of inherent patterns, Kubik is indirectly acknowledging a schema-based process which is shaped by learning and experience.

Wegner attempts to clarify Kubik's ideas about the relationship between inherent pattern perception and the principles of Gestalt psychology, highlighting that several principles compete in this music to shape the resulting percepts. Wegner recognises the function of the principle of 'belongingness' (relevant to figure-ground organisation) in his comment that "a tone in an amadinda composition can perceptually be part of only one inherent pattern at a time" (Wegner, 1993, p. 207). Here, he is referring to the rule of exclusive allocation, which is responsible for the fact that we can switch from one pattern to the other, but cannot perceive both at the same time. Also with reference to the principle of belongingness, Wegner states that:

> In the course of the signal parsing process, inherent patterns arise as illusory percepts. Viewed from the angle of perceptual psychology, the general incongruity of the "played image" and the "heard image" in many East and Central African musical traditions (Kubik, 1962) appears as a distinction between real and illusionary sound sources. (Wegner, 1993, p. 209)

Wegner suggests that the principle of 'similarity' can be observed in the "high amount of redundant input information offered by an amadinda xylophone performance" (p. 207). The fact that inherent patterns move within narrow pitch ranges is attributed to the proximity principle. Wegner (1993) agreed with Kubik that the "predominant use [of the Kiganda-fourth] as an interlocking interval guarantees the appearance of this audio-psychological phenomenon... Fourths interlocking greatly favours hearing at two or three pitch levels" (Kubik, 1969, p. 35). He also acknowledges that the strength of the proximity principle is enhanced by the fast tempo of the pitch sequence. Although Wegner suggests that proximity is the predominate percept-shaping factor, he states that all musical parameters potentially influence the perceptual organisation of inherent patterns. Spatiality is another factor that was identified as enhancing the strength of segregation. For example, "close spacing", that is, the physical position of performers, "makes the identification of the two "sound sources" (musicians) impossible in favour of the emergence of new inherent percepts" (Wegner, 1993, p. 209).

In addition to Gestalt principles of organisation, Wegner acknowledges the role of schema-based processes, that is, the fact that expectancies play an important role in the shaping of a percept. Unlike Kubik, Wegner specifies that the "culture-specific element here is a variable which directs the listener's attention and expectation, based on general rules of auditory perception" (Wegner, p. 216). He claims that the two processes, primitive and schema-based, compete with each other in the perception of amadinda xylophone music.

In this study, Wegner (1993) considered not only the perception of inherent patterns, but also how inherent patterns function into the overall musical context, that is, in combination with a "vocal nuclear theme". He distinguishes between the two components of the composition by stating that the theme only "makes sense" within the realm of Kiganda culture, but will go unnoticed by the "outsider", that is, "the cultural meaning alone shapes the percept" (p. 217). In relation to the inherent patterns on the other hand, Wegner suggests that listeners will hear basically the same patterns regardless of culture, emphasising the role of primitive organisational processes.

In a series of experiments, Wegner's (1993) objective was to test the "intercultural validity of Gestalt laws by disenabling them in modified standard performances" (p. 220). He taped authentic and synthesised versions of four amadinda xylophone compositions, introducing several deviations. These included tempo changes, shifts of tone impacts, different timbres, different pitch levels, and different spatial qualities. Nine Buganda musicians participated in the experiment. Presentations consisted of authentic versions, followed by their synthesised counterparts, and listeners were asked to vocalise what they heard during the listening period, then provide verbal descriptions of their perception of the music. Wegner specified that the experiment was not designed to provide data which could be statistically evaluated like in controlled laboratory experiments designed by experimental psychologists. His data suggested however, that a significant amount of "perceptual disorientation" was experienced by listeners as a result of disenabling Gestalt groupings.

Implications of Cross-Cultural Research

Wegner's research raises some important questions which have not been considered elsewhere in the literature. Significantly, he is the only author to consider cultural influences on stream segregation as they apply to music. While Wegner's study did not directly compare different cultural groups (Buganda and non-Buganda listeners), he tested the intercultural validity of Gestalt laws by disenabling them in modified performances of amadinda xylophone music.

In order to assess the extent to which culture influences the clarity of resulting patterns in Reich's phase-shifting music, I conducted a comparative study which tested both Western and non-Western listeners on the same set of musical patterns. Appendix A reports the methodology and results of the study. Specifically, the aims of the experiment were:

1. to see if the resulting patterns in Reich's *Piano Phase* were the same or different for Western and Erromangan[7] listeners; and
2. to measure the degree to which listeners could isolate specific patterns within the musical texture.

The results showed that Erromangan listeners found it significantly easier to isolate resulting patterns in *Piano Phase* than Western listeners, despite no prior exposure to Western art music. In summary, the results suggest that cross-cultural studies of auditory stream segregation have the potential to inform an understanding of the complex relationship between primitive and schema-based segregation processes.

Summary

The first section of the literature review revealed that the majority of studies in this area focus on 'non-musical' stimuli. That is, they test listeners' responses to simple repetitive patterns, to observe factors which influence the segregation of streams. While these studies provide a foundation for exploring the role of grouping processes

[7] Erromango is a southern island of Vanuatu.

in music, I have argued that the challenge lies in going beyond providing perceptual evidence for what is known intuitively by musicians and composers.

The fact that the patterns in Reich's phase shifting music are deliberately ambiguous, provides an opportunity to consider the variability of these works in view of what is known about the way patterns behave under certain conditions. In particular, it provides an opportunity to consider the extent to which listeners can shape their own experience of these works. The studies reviewed throughout the chapter therefore provide the foundation for a theoretical evaluation of the role of stream segregation in Reich's music (Chapter 4).

The various methodologies which have been used to explore perceptual grouping processes were reviewed in section two. An evaluation of measures determined that the pattern recognition task was the most suitable measure for exploring the role of stream segregation, and the salience of resulting patterns, in Reich's music. Experiments 2A and 2B, reported in Chapter 6 of the study, use this method to explore the nature of resulting patterns in *Piano Phase*.

The third section of the review surveyed studies which clarify differences between primitive and schema-based segregation processes. While the influence of familiarity and attention has been explored with regard to stream segregation, the influence of musical experience has not been considered in any detail. That is, no studies cited in the literature specifically considered the extent to which a knowledge of musical structure influences listeners' ability to isolate patterns. For this reason, the experiments reported in Chapter 6 collected responses from both musicians and non-musicians, to consider the influence of musical experience on listeners' ability to isolate resulting patterns in Reich's *Piano Phase*.

The final section of the survey outlined the few studies which have explored the role of stream segregation in musical examples. According to Bregman and Wright (1987), the investigation of polyphonic music according to streaming principles, "demystifies certain well-established principles of traditional music theory..." (p. 63). Similarly, the Huron studies (1989, 1989a, 1991) "demonstrate a significant agreement between compositional practice in polyphonic music and empirical research concerning auditory stream segregation" (p. 102). Rather than providing confirmation for what is already well established in music theory, the present study attempts to use the principles of stream segregation to make a contribution to music theory. I suggest two primary differences between the present study and those studies mentioned above, which provide support for such an attempt. First, like the Wegner (1993) study, Reich's music is variable in nature. That is, the resulting patterns in Reich's phase shifting compositions, which form the listener's experience of the music, are incongruous with the sensory input produced by the performers. This suggests that research on perceptual grouping processes can be used to inform our understanding of the nature of resulting patterns, and the extent to which listeners can organise their own experience of the music. Second, the parameters of Reich's phase shifting works are largely unvarying, and as suggested by the literature reviewed, the highly repetitive nature of the music increases its potential for psychological investigation.

Chapter 4

Analysis of Steve Reich's Phase Shifting Music

Introduction

In this chapter, I present a critical analysis of three of Reich's instrumental phase shifting works, *Piano Phase* (1967), *Violin Phase* (1967), and *Phase Patterns* (1970), as a basis for answering the question: *Can stream segregation theory contribute to the understanding of temporality in Reich's music in ways that are not possible via formal musicological analysis?* In a prelude to the analysis, I argue that Reich's essay, "Music as a Gradual Process" (1974), demonstrates an awareness of the contribution of perceptual grouping processes to the event of these works. In addition, I suggest that Reich was aware of the implications of active and passive listening on the perception of 'resulting patterns'. A section on resulting patterns is included prior to the analysis to demonstrate that they are central to, and to a large extent, characterise the experience of this music. I believe that the level of ambiguity in the perception of patterns in Reich's early works can be attributed to the streaming capacity of the compositional material, and that this virtue has contributed to a methodological stalemate for musicologists. Prior to the analytical component of this chapter, I have included several comments by prominent musicologists to support this view.

One of the few attempts to formally analyse Reich's early works is a study by Richard Cohn, titled "Transpositional combination of beat-class sets in Steve Reich's phase shifting music" (1992). Cohn's analysis of *Violin Phase* and *Phase Patterns* supports his argument that Reich's choice of musical material was governed by his concern for achieving "maximum possible differentiation" within the constraints of the phase shifting process. In the second section of this chapter, I have extended the analysis to *Piano Phase*, and to other dimensions of *Violin Phase* and *Phase Patterns*, to identify points of structural significance, to explore the nature of resulting patterns under transformation, and to search for further evidence of "maximum possible differentiation".

Cohn makes several assumptions about the temporality of Reich's early works as a result of his application of set theory. For example, he argues that the frequency of attack-points in each region, and their overall design, demonstrates a progressive quality, and therefore reflects linear characteristics. In Chapter 2, I proposed an analytical paradigm for musical time, which incorporated several different perspectives: formal, analytic, empirical, and experiential. I argued that a study of musical time restricted to one approach, such as Cohn's critical analysis (analytic/empirical), was worthy and informative in its own right. I also argued however, that some important information about musical time is obtained by considering the points of similarity and divergence across these different perspectives. For example, I argue that a multifaceted approach to temporality focusing on certain types of contemporary music would display a considerable amount of divergence between different approaches, while more traditional linear forms of music would display a higher level of agreement across approaches.

In the third section of this chapter, the question of linearity in Reich's music is approached from a different perspective. The principles of auditory stream segregation are used to demonstrate how resulting patterns are formed, and to suggest how they participate in the experience of Reich's music. In addition, these principles are used to challenge the notion that registral beat-class sets are the most salient patterns within the musical texture. I have also considered the question: *To what extent does musical experience and background contribute to the salience of resulting patterns*? Such a question is necessary to investigate the extent of perceptual ambiguity, and to demonstrate how conventional analysis can be supplemented by perceptual analysis to address the issue of perceptual variability.

Music as a Gradual Process

> Performing and listening to a gradual process resembles: pulling back a swing, releasing it, and observing it gradually come to rest; turning over an hour glass and watching the sand slowly run through to the bottom; placing your feet in the sand by the ocean's edge and watching, feeling, and listening to the waves gradually bury them. (Reich, 1974, p. 9)

Before discussing the phase shifting process, and the patterns generated by this process, it is important to consider comments related to the temporal characteristics of Reich's "Music as a Gradual Process". In relation to minimalist forms in general, Robert Schwarz (1980) states that:

> The resultant art is one in which contrast and change, and even the progression of time itself, can only be appreciated at a much slower rate than that to which we are normally accustomed. (Schwarz, 1981, p. 376)

This comment relates strongly to Reich's statement that "by restricting oneself to a single, uninterrupted process, one's attention can become focused on details that usually slip by" (Schwarz, 1981, p. 376). Although the term minimalism has been used to describe Reich's earlier works; that is, those works based on "perceptible processes", the label has been used less frequently to describe compositions written after 1971. In his later works, Reich becomes gradually less concerned with the idea of audible structures. Consequently, the appropriateness of the term minimalism for describing Reich's music is reserved for discussion in Chapter 7, after the musicological and perceptual analysis has been presented.

Schwarz (1981) addresses the idea that in Reich's early music, sound and structure are identical. In this sense, structure serves a purpose other than providing a framework which supports an array of sounds. An obvious feature of all of Reich's early works is the presence of a repeated, driving pulse, in combination with the concept of a clear and usually unchanging tonal centre. Schwarz claims that the use of repetition coupled with this unvarying rhythmic pulse "satisfies the minimalist ideal of forcing the mind inward on small structural details, while simultaneously becoming the prime unifying force" (Schwarz, 1981, p. 378).

Schwarz (1981) also acknowledges that Reich's use of repetition has the capacity to distort the listener's comprehension of the passage of time. He points out that despite the constant pulse present in Reich's music, many listeners experience a lack of awareness of the passage of time. In his view, Reich's music proceeds so tonally pleasantly that it obstructs the tonal understanding of time.

In general, music as a gradual process removes the emphasis on the linear relationship between larger structural events, and provides a gradually evolving textural surface from which listeners can extract patterns concealed within the fabric of the music. The relationship between this type of interaction, and visual figure/ground reversal, suggests an experience that has more to do with depth perception and the alternation of figures than one concerned with anticipating future events.

The audibility of the process in Reich's early works is a point in question. The phase shifting process can be detected in the sense that we can perceive the principal pattern moving gradually ahead of its duplicate, and settling into a new guise. We are aware that the process is in place, and expect accelerations to occur a number of times throughout the music. In addition, certain moments of the acceleration cycles are distinctive, such as the doubling of tempo experienced at the half way point. In this sense, it is fair to say that the process and the sounding structure are related. This does not mean, however, that the resulting patterns are predetermined in the same way.

The Phase Shifting Process

The phase shifting process was adopted by Reich in a number of his early compositions. The examples explored in this chapter are restricted to the instrumental phase shifting works for reasons stated in the introduction to the thesis. Reich articulates the origins of the process in the following comment:

> My first thought was to play one loop *against itself* in some particular canonic relationship... In the process of trying to line up two identical tape loops in some particular relationship, I discovered that the most interesting music of all was made by simply lining the loops up in unison, and letting them slowly shift out of phase with each other... This process struck me as a way of going through a number of relationships between two identities without ever having any transitions. It was a seamless, continuous, uninterrupted musical process. (Reich, 1974, p. 50)

The first applications of the process are explicit in *It's Gonna Rain* (1965), *Come Out* (1966), and *Melodica* (1966). The first two examples were created using tape loops consisting of recorded speech as previously discussed in Chapter 2. Reich's concern with adapting the process for live performance is expressed in the following comment:

> ...it seemed to me at the time impossible for two human beings to perform that gradual phase shifting process since the process was discovered with, and was indigenous to, machines. (Reich, 1974, p. 51)

Later however, Reich apprehended that it was possible to "perform this process without mechanical aid of any kind" (p. 52). *Piano Phase* (1967), Reich's first phase shifting piece for live musicians, is the embodiment of this realisation. The phase shifting process offers the performer freedom from traditional notational constraints, allowing them to become "totally absorbed in listening..." (p. 52). The procedure used to execute the phase shifting process in a live performance of *Piano Phase* is as follows:

> ...two musicians begin in unison playing the same pattern over and over again... while one stays put, the other gradually increases [the] tempo so as to slowly move one beat ahead of the other. This process is repeated until both players are back in unison, at which point the pattern is changed, and the phasing process begins again. (Reich, 1974, p. 52)

Reich (1974) states that often musical material will suggest a certain type of process, and similarly, processes may induce ideas for the kind of musical material to be run through them. Reich also stated that he was not concerned with whether or not a musical process is realised through human performance or by mechanical means as long as the music itself is interesting. Reich's instruction to performers, specifying "mechanical playing", is discussed at a later stage with regard to factors influencing stream segregation in these works.

Although Reich (1974) claims that musical processes have the ability to put one in touch with the "impersonal", he also admits to having "a kind of complete control" (p. 10). For example, "by running this material through this process I completely control all that results, but also that I accept all that results without changes" (p. 10). In terms of compositional processes, the difference between Reich's music and examples of John Cage's chance and indeterminate music, is that the processes used by Cage were not perceptible ones. Reich's concern for perceptible processes is expressed in his comment that he is interested in "a compositional process and a sounding music that are one and the same thing" (p. 10). He states that there is no room for improvisation in a musical process because the concepts are "mutually exclusive" (p. 11). Although the number of lines subject to phasing, and the symmetric division of the beat cycle differs in each of Reich's instrumental phase shifting works, the concept of phase shifting is essentially the same. A simple recurring pattern operating within the phase shifting process is capable of creating a complex array of sounds. Assuming the process involves a complete phasing revolution of the primary pattern, longer patterns are capable of outputting a greater level of complexity. The phase shifting process is comparable to the concept of a canon, which basically implies 'self-similarity' on some level. In its optimum state, self-similarity "is symmetry across scale... impl[ying] recursion, pattern inside of pattern" (Gleick, 1987, p. 103). In other words,

> Non-linearity causes small changes on one level of organisation to produce large effects at the same or different levels... In general, non-linearity produces complex and frequently unexpected results.
> (Peter Coveney & Roger Highfield, 1995, p. 9)

In my opinion, descriptions of other physical systems exhibiting phase transitions are useful for comparative purposes. For example, the quote above can be likened to the experience of sudden perceptual shifts in Reich's phase shifting music, which occur as a result of a gradual process. In particular, the point at which the patterns emerge out of an acceleration region and re-stabilise in a new phase is perceived as abrupt, despite the fact that the rate of acceleration is relatively constant. A musicological interpretation of the behaviour of the phase shifting process is offered by Epstein:

> Sudden perceptual shifts occur when phasing has progressed to the point where one configuration is no longer viable and is replaced by another. In such cases the discontinuity is purely perceptual, the actual change being one of degree. As we have seen, perceptual shifts - voluntary or involuntary - also take place in the total absence of change in the music. The likelihood of such shifts, which are akin to figure-ground reversal, increases in proportion to the degree of ambiguity of some aspect of the music. (Epstein, 1986, p. 502)

As mentioned, events which duplicate motifs, or mirror motifs in different dimensions are described as containing elements of self-similarity. Once again, a description of alternative systems provides a suitable analogy for the moment at which the chaotic acceleration regions revert to an 'immobile' state:

> Like so much of chaos itself, phase-transitions involve a kind of macroscopic behaviour that seems hard to predict by looking at the microscopic details. When a solid is heated, its molecules vibrate with the added energy. They push outward against their bonds and force the substance to expand. The more heat, the more expansion. Yet at a certain temperature and pressure, the change becomes sudden and discontinuous... The average atomic energy has barely changed, but the material...has entered a new realm. (Gleick, 1987, p. 127)

This comment reminds us of earlier descriptions of Reich's music which suggest that the micro- and macroscopic structure of his music is essentially the same. If, however, macroscopic implies what is perceived, and microscopic denotes the details of the gradual temporal shift of the accelerating pattern, there is a considerable amount of disparity between them. This disparity is also apparent in the prolongation regions of the music, in which perceptual shifts "take place in the total absence of change" (Epstein, 1986, p. 502). In this sense, perceptual shifts refer to the oscillation between available percepts. When a latent percept is brought into the foreground of perception, it is described as a 'resulting pattern'.

Resulting patterns

> We have a rigorously defined system, a process that is continuous and free of external intervention for expressive, formal, or other aesthetic reasons. Where, then, are the mysteries? They are in fact numerous and stem from the fact that while the process is continuous, our perception is not. The listener is presented with a rich array of possibilities out of which he/she may construct an experience of the piece. (Epstein, 1986, p. 497)

The self-replicating nature of the phase shifting process, and the intervallic structure of musical material, lead to a decomposition of the principal patterns into smaller units or sub-patterns. I argue that the emergence and disappearance of such patterns are determined, to a large extent, by a combination of primitive and schema-based segregation processes. The term "inherent pattern", introduced by Kubrik in the 1960's, is used to describe a perceived pattern which emerges from the interlocking structure of Bugandan xylophone music (discussed in the final section of Chapter 2). In my opinion, the word 'inherent' in this context suggests a pattern that follows the constituent elements of the music, as they exist physically. The term 'resulting patterns' is preferred in this study because it suggests patterns that have emerged as a consequence of something else; in this case, stream segregation, a process which prohibits the actual temporal order of events from being perceived as such. In addition, the term inherent pattern unnecessarily confuses the distinction between inherent and perceived structures which was introduced in Chapter 2.

As suggested by Epstein (1986), resulting patterns "may seem to impose themselves on the listener, or the listener may "actively cultivate them"" (p. 497). In this comment, Epstein indirectly acknowledges the distinction between the role of primitive and schema-based organisation. The latter incorporates selective listening, where the listener deliberately seeks out a particular pattern, or moves back and forth among several alternatives. It should be pointed out that resulting patterns are by no means exclusive to the prolongation regions of the music, but are equally viable during accelerations.

Reich (1974) draws attention to the fact that the use of perceptible processes does not eliminate the element of mystery from the music. These mysteries he describes as the "impersonal, unintended, psycho-acoustic by-products of the intended process", and include sub-melodies, stereophonic effects, and slight irregularities in performance such as harmonics. The "sub-melodies heard within repeated melodic patterns" that Reich describes are the resulting patterns. The specific influence of factors such as spatiality (listener location) and synchronicity (slight irregularities in performance) on the clarity of resulting patterns are considered in the third section of this chapter. Reich states that it is these irregularities in the music which make repeated listening interesting, that is, "...[the music] always extends farther than I can hear" (p. 11). In addition, Reich claims that the minute details present in the music become apparent when one sustains close attention. In relation to *Violin Phase* (1967), Reich states:

> I became clearly aware of the many melodic patterns resulting from the combination of two or more identical instruments playing the same repeating pattern one or more beats out of phase with each other. As one listens to the repetition of the several violins one may hear first the lower tones forming one of several patterns, then the higher notes are noticed forming another, then the notes in the middle may attach themselves to the lower tones to form still another. (Reich, 1974, p. 53)

The significance of "identical instruments" in relation to the formation of resulting patterns is discussed according to timbral influences on the formation of streams in the third section of this chapter. The current point of interest however, is Reich's acknowledgment that "it is the attention of the listener which will largely determine which particular resulting pattern he or she will hear at any one moment" (Reich, 1974, p. 53). This point is enhanced by Schwarz's comparison of Reich's music and ambiguous visual forms:

> Just as in op[tical] art our eyes perceive visual illusions which are not present in reality, such as reversing cubes, three-dimensional effects, and perspective shifts, so too in *Come Out* our ears psycho-acoustically fixate upon various transitory patterns which arise out of the phasing

> process. (Schwarz, 1981, p. 385)

Schwarz's use of the term transitory implies that the resulting patterns are ephemeral, volatile, and short-lived. The transitory nature of resulting patterns accentuates the fact that the emergence and disappearance of patterns is central to the musical experience of these works. This issue is absorbed into the central question posed in my thesis: *How does pattern participate in the perception and experience in Reich's early works?* The degree of freedom the listener has, in terms of extracting patterns from the musical texture, is discussed in the thesis according to the limitations of the perceptual system.

> Listening to an extremely gradual musical process opens my ears to *it*, but *it* always extends farther than I can hear, and that makes it interesting to listen to that musical process again. That area of every gradual (completely controlled) musical process, where one hears the details of the sound moving out away from intentions, occurring for their own acoustic reasons, is *it*. (Reich, 1974, p. 11)

The unvarying parameters in Reich's phase shifting music create a musical texture which is susceptible to segregation. Patterns occurring "for their own acoustic reasons" come about as a result of primitive grouping processes. I argue that by removing any 'perceptual bias' from the music, that is, by not clearly distinguishing figure and ground, a range of resulting patterns is ensured. In Chapter 2, I described the process of 'pointing out' various features within the texture as 'freezing the play of the system'. The fragile equilibrium created by the musical material and the phasing process, which allow alternative patterns, can be shifted in favour of one percept or another. Reich recognises this phenomenon, and incorporates it into the design of *Violin Phase* and *Phase Patterns*, where patterns inherent in the musical texture are brought to the surface of the texture through instrumental doubling. Reich guides the attention of the listener by doubling one of the pre-existing patterns with the same instrument:

The pattern is played very softly, and then gradually the volume is increased so that it slowly rises to the surface of the music and then, by lowering the volume, gradually sinks back into the overall texture while remaining audible. The listener thus becomes aware of one pattern in the music which may open his ear to another, and another, all sounding simultaneously in the ongoing overall texture. (Reich, 1974, p. 54)

It should not be assumed that any combination of notes in the musical texture will be successfully extracted by listeners. I argue that there are perceptual limitations to the types of patterns that can be extracted on the basis of primitive stream segregation rules. This argument is reflective of Bregman's theory which states that primitive processes serve to partition auditory sequences, while schema-based processes select patterns within auditory streams. The question of whether or not resulting patterns can be formed across auditory streams is raised in response to Epstein's suggestion that the sequence in Figure 4-1 represents a potential resulting pattern.

Figure 4-1 Resulting pattern for phase 2 ($T_{0,10}$) suggested by Epstein (1986)

Source: Adapted from Epstein, 1986, p. 500

The original barline falls between the 6th and 7th semiquaver of the suggested resulting pattern.

Phase 2 (T0,10)

Suggested resulting pattern

The resulting pattern shown in Figure 4-1 is not likely to 'obtrude' itself on the listener, because the primitive segregation process obscures the temporal order of events, making it difficult to cross the point of intersection between streams. The most obvious question to be asked here is: *Does learning, and familiarity with a pattern, allow listeners to overcome primitive segregation rules?* Problems of this nature are reminiscent of those dealt with by Dowling, who investigated the perception of interleaved melodies (reviewed in Chapter 3). The question of familiarity is raised here because it is important in assessing the limitations of formal music analysis.

Approaching Analysis: Conflicting Views

The use of perception research in application to Reich's phase shifting music adds a new dimension to the issue of whether or not Reich's early music is worthy of analysis. In his essay, *Music as A Gradual Process* (1974), Reich makes a clear distinction between the process of composition, and pieces of music that are literally processes. As stated earlier, at this time, Reich was not interested in hidden structures, such as those employed by serialists, but in "perceptible processes". For example, Reich states, "I don't know any secrets of structure that you can't hear" (p. 10).

According to Cohn, this conclusion hardly encourages the analysis of Reich's music: "If there is nothing in the bones that is not in the skin, analysts may as well leave their surgical instruments at home, and this is exactly what most have done" (Cohn, 1992, p.147). Dan Warburton (1988) suggests that Reich's early music, which includes his phase shifting music, is restricted to description because it combines "overall form and moment-to-moment content" (Cohn, 1992, p. 147). Similarly, Wim Mertons (1972) states that this kind of experimental music is ateleological and non-narrative, and that "no one sound has any greater importance than any other" (p. 88). This view is supported once again by Jonathan Kramer (1988) who defines examples of the early minimalist repertoire as "uncompromisingly vertical" (p. 386). As specified in Chapter 2, Kramer uses the concept of verticality to describe music in which "the temporal continuum is unstructured by beginning, closure, climax, contrast, or progression, so that the significance of the sequential order of events, and their dependence on each other, is minimised" (Cohn, 1992, p. 147).

If these comments are reconsidered in view of auditory perception research however, their significance wavers. For example, Kramer's suggestion that "the significance of the sequential order of events, and their dependence on each other, is minimised", can be reversed. The argument becomes: "the sequential order of events, and their dependence on each other" is precisely what generates the resulting patterns that are central to the temporal experience of this music. Although the order of perceived events may not be specifically revealed using formal analytical procedures derived from music theory, it is possible to form descriptions of the temporal experience by turning to perception research, specifically, auditory scene analysis.

In relation to the temporal experience, Clytus Gottald (cited in Cohn, 1992), claims that Reich "got round the problem of the articulation of time by denying the existence of time" (p. 147). Similarly, Kramer states that:

> ...music cast in vertical time can scarcely be analyzed, in the usual sense of the term... It is essentially pointless to explicate a holistic, timeless experience in terms of sequential logic. Thus most discussions of nonteleological music are more descriptive - or prescriptive - than analytic. (Kramer, 1988, p. 388)

The consistent argument reflected in many of these comments is confronted by Richard Cohn (1992), who uses a rhythmic adaptation of pitch-class set theory to reveal structural characteristics of Reich's phase shifting music. Cohn argues that Reich's choice of pitch material reflects his concern with achieving "maximum possible differentiation within the constraints of the phase shifting process" (p. 164). Cohn's analysis reveals what he describes as linear progressions (created by the series of attack-point frequencies), and suggests that the "goal-directed" structure must ultimately shape a listener's experience of time.

My argument is that the variation in attack-points from one phase to another may not be salient enough to significantly contribute to a listener's sense of direction and movement in this music. Instead, I propose that the competition that exists between the vertical and horizontal aspects of the music, causing the listener to segregate the music into auditory streams, has an equal, if not more direct impact on the temporal experience. A major concern of this study is to establish whether or not this more immediate perceptual experience dominates over the perception of larger structural sections in terms of a listener's experience of time and motion.

The argument that Reich's music is unsuitable for analysis is further challenged by Epstein (1986). Although Epstein's analysis is based in musicology, he does acknowledge the importance of the role of perceptual processes in the construction of the musical experience:

> ...the role of composer is not as inventor of personal codes for us to decipher but as a discoverer of impersonal natural phenomena. In experiencing process music, the listener's task is also one of discovery - of the physical laws embodied in the process and of the psychological laws affecting the listener's interaction with the process. It is in this interaction that the coming together of impersonal and personal takes place that forms the key experience of process music. (Epstein, 1986, p. 494)

This comment implies that process music involves a relinquishment of control on the part of the composer. It also suggests that the phase shifting process, the musical material, and the perceptual system itself, form an interactive relationship, which results in a variable and potentially ambiguous musical experience. The capacity of formal theoretical analysis to express the fragility of this interaction is considered below.

Set Theory Analysis

Introduction

Cohn (1992) applied a rhythmic adaptation of pitch-class set theory to two of Reich's instrumental phase shifting works, *Violin Phase* and *Phase Patterns*. Cohn's analysis reveals similarities between the two pieces on a number of levels. For example, by calculating the frequency of attack-points and doubled attacks in these compositions, Cohn revealed that both works contain a progressive structure, in the sense that the density of attack points increases as the compositions move through the phase shifting process. These findings are the foundation of Cohn's argument that Reich's choice of musical material reflects his concern for achieving "maximum differentiation within the constraints of the phase shifting process" (p. 167). Cohn reassesses the "vertical" label attached to Reich's early works by arguing that they possess attributes that could only be described as linear.

An inquiry into Cohn's reasoning is carried out in the following section by extending the analysis to *Piano Phase*, and to other dimensions of *Violin Phase* and *Phase Patterns*. This inquiry is intended to test the validity of his argument. The following section necessarily reviews all three compositions so that direct comparisons can be made between them, and so that the credibility of beat-class set theory in application to these works can be assessed as a whole. Cohn provides the following explanation for his choice of approach:

> Given the relative poverty of our rhythmic terminology, the challenge for the theorist is to discover a means to characterise this material that is not only descriptively adequate, but also allows for exploration of its properties, its behaviour under transformation, and its relation to other potential material. (Cohn, 1992, p. 149)

Cohn takes advantage of the correspondence between metric cycles, and the 12 pitch-class universe, suggesting that "much of the technology developed for atonal pitch-class analysis is transferable to the rhythmic domain..." (p. 149). His analysis draws on a combination of approaches derived from the following sources: Milton Babbitt, "Twelve tone rhythmic structure and the electronic medium" (1962); Benjamin Boretz, "Sketch of a musical system" (1970); John Rahn, "On pitch or rhythm: Interpretations of orderings of pitch and time" (1975); and David Lewin, "Generalised musical intervals and transformations" (1987).

The analysis of Reich's phase shifting music presented in this section is divided into five parts, which reflect the issues considered in Cohn's analysis:

A Materials and Content

B Form and Process

C Materials and Process: Attack Point Frequencies

D Equivalence and Inclusion Relations

E Critical, Stylistic, and Aesthetic Implications

Section A exposes the principal patterns in each of the three instrumental phase shifting works, and isolates their principal beat-class sets. Generating intervals, isomorphic relationships, cardinalities, and the presence of the deep scale property are also addressed. Section B highlights the way in which the phase shifting process has been implemented in each example, and identifies structural links between them. Section C investigates beat-class sets that arise from composite patterns (brought about by the phase shifting process), allowing an assessment of broader structural characteristics. This section also examines the cardinality of the union of the principal *bc set* with each of its transpositions, and assesses the overall nature of attack-point design. Interval class (ic) vectors are established in order to further examine the presence of the deep scale property, which, according to Cohn, is "a necessary condition for maximum variety" (p. 154). Section D of the analysis reveals the presence of equivalence, inclusion, and complement relations between the beat-class sets that result from transpositional combinations. The final section of the analysis readdresses the notion of verticality in Reich's phase shifting compositions. The paradoxical relationship between process and 'timelessness' is explored in view of analytical findings.

<u>A: Musical Material</u>

Principal Beat-Class Sets

Piano Phase uses a twelve beat cycle (mod-12 system), where each beat is articulated in the principal pattern (Figure 4-2).

Figure 4-2 Principal pattern of *Piano Phase*

According to the rules of Gestalt psychology, and auditory stream segregation, the principle of proximity predicts two main registral groupings in section A of *Piano Phase.* The set formed by the low E and F# (Figure 4-3) is {01569}; the prime set is [01478].

Figure 4-3 Pattern formed by the low registral set of *Piano Phase*

The set formed by the higher register, B, C# and D (see Figure 4-4) is characterised by the attack-points {2,3,4,7,8,10,11}; the prime form of the set is [0125689].

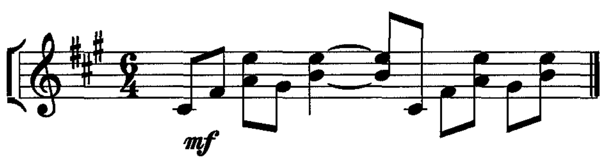
Figure 4-4 Pattern formed by high the registral set of *Piano Phase*

Although it is argued that resulting patterns (bc sets) are not restricted to the registral grouping of constituent elements, the beat-class sets under analysis conform to groupings *likely* to emerge according to the principle of proximity in Gestalt psychology. The perceptual salience of registral beat-class sets is investigated in Chapter 6 of the thesis, which reports an experimental inquiry intro the clarity of auditory streams. Resulting patterns which do not conform to registral grouping will be discussed with reference to schema-based organisation principles later in the present chapter. Cohn's (1992) analysis does not consider resulting patterns other than those formed by the registral characteristics of the principal patterns. Therefore, the significance of structural characteristics derived from the analysis is determined by testing the perceptual salience of these patterns (see Chapter 6).

The following analysis isolates registral bc sets so that direct comparisons can be made with Cohn's analysis. The implications of restricting the analysis to registral sets are discussed further in the third section of this chapter, which considers the fragility of registral sets according to van Noorden's coherence and fission boundaries (1975), and the results of the Bregman and Pinker (1978) experiment discussed in Chapter 3.

In *Violin Phase*, the twelve beat cyclề comprising the principal pattern shown in Figure 4-5 segregates into three main beat-class sets due to its broad registral span.

Figure 4-5 Principal Pattern of *Violin Phase*



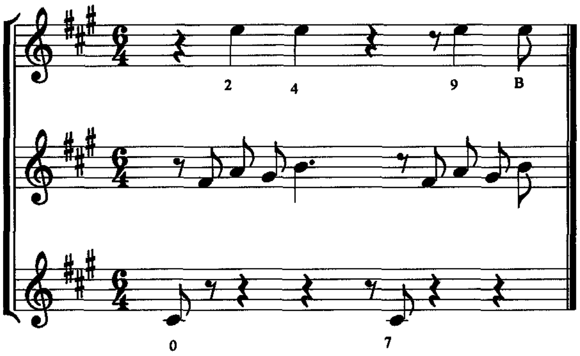
Cohn isolates the following beat class sets in *Violin Phase* (see Figure 4-6):

1. the set formed by the low C# {07}; prime form [05]
2. the set formed by the high E attacks, (also equivalent to the set of double stops), {249B}; prime form [0257], and
3. the set formed by the *union* of the registral extremes {02479B}; prime form [024579].

Cohn's justification of beat-class sets stems from Reich's comment that "the highest and lowest registers... possess strong individual identities as "psycho-acoustic by-products" (p. 150). The notes in between the registral extremes (see Figure 4-6) are given less attention in Cohn's analysis, suggesting that intermediate notes are *not* likely to form a discrete unit, and that they may divide their allegiance between notes from other sets. Reich (1974) himself states that "the notes in the middle may attach themselves to the lower tones to form still another [pattern]" (p. 53).

Figure 4-6 Principal beat-class sets of *Violin Phase*

Source: Cohn, 1992, p. 151



Phase Patterns presents a unique case, in that the most significant beat-class sets are assumed to be formed by the notes played by each hand as shown in Figure 4-7.

Figure 4-7 Principal pattern of *Phase Patterns*

The right hand set {1467}and the left hand set {0235}of the mod-8 cycle are equivalent under transposition. That is, they share the prime form [0235]. I argue that the range of resulting patterns generated by the phase shifting process using this material is limited by the combining power of simultaneous elements. For this reason, notes defining the outer registral boundaries of the pattern are likely to be more salient, and therefore have a greater bearing on the perceived rhythmic sets.

Generating Intervals and Cardinalities

Cohn identifies similarities between *Phase Patterns* and *Violin Phase* in that their primary bc sets are all cyclically generated by the smallest nonunit prime interval greater than 1.

> This generating interval is 3 for the mod-8 system of *Phase Patterns*, and 5 for the mod-12 system of *Violin Phase*... The principal bc set of *Phase Patterns*, [0235], is the 3-generated set whose cardinality is half the size of the system. All three principal sets in Violin Phase are 5-generated, and the cardinality of the largest of them, [024579], is also half the size of the system. (Cohn, 1992, p. 150)

The generating interval for the mod-12 system of *Piano Phase* is also 5 (the smallest nonunit prime interval >1). However, the cardinalities of the principal bc sets for *Piano Phase* (the number of attack-points per cycle in each register) do not constitute even ratios to the mod-12 system. The lower register [01478] has a cardinality of 5. The higher register [0125689] has a cardinality of 7.

Jeff Pressing (1983) has stated that many commonly used pitch-class systems are characterised by generability from the smallest nonunit prime. In addition, Pressing (cited in Cohn, 1992) states that "beat-class sets cyclically generated from non-unit primes are fundamental to much music of West Africa and of African- influenced cultures in the Western Hemisphere" (p. 151). This supports the suggestion that the influence of African music on Reich's output is not restricted to compositions after his study of African drumming in 1970.

Isomorphic relationships

Cohn highlights isomorphic relationships in *Violin Phase,* specifically, that the primary pc set, [024579], corresponds with the largest of the bc sets (the union of the registral extremes). A second relationship can be found between the low set [0257], and the chain of perfect fourths existing within the pitch material: C#-F#-B-E. In order to test the assumption that isomorphic relationships are a general feature of these works, I will briefly consider Reich's other two phase shifting works. The pitches used in *Piano Phase* {B,C#,D,E,F#} create the prime pc set [02357] which does not correspond with either of the primary bc sets identified above. The pitch material in *Phase Patterns* comprises the prime pc set [03578], which, once again, does not share an isomorphic relationship with its principal bc set.

Gamer's deep scale property

> a set holds the deep scale property if its dyadic subsets (ie. its interval classes) are distributed such that each dyad class is represented with a unique multiplicity. (Cohn, 1992, p. 150)

Interval class (ic) vectors are calculated by subtracting the number of attack-points in each phase from the total number of beats per cycle. The set formed from the ic vectors in *Phase Patterns,* [41230], holds the deep scale property because it is made up of non-repeating numbers. The largest principal set of *Violin Phase* [024579] also satisfies the deep scale condition. In a later discussion, an examination of ic vectors reveals that *Piano Phase* does not hold the deep scale property. This suggests that the musical material in *Piano Phase* does not output the same level of rhythmic variety offered by *Violin Phase* or *Phase Patterns* when run through the phase shifting process.

B: Form and Process

The analysis that follows concentrates on the prolongation regions of *Piano Phase* which, according to Cohn (1992), constitute the "dynamic form-shaping characteristics of this music" (p. 152). Following Cohn's method, consecutive prolongation regions for *Piano Phase* would be labelled to represent the series as follows:

$$\{T_{0,0};\ T_{0,11};\ T_{0,10};\ T_{0,9};\ T_{0,8};\ T_{0.7};\ T_{0.6};\ T_{0.5};\ T_{0,4};\ T_{0,3};\ T_{0,2};\ T_{0,1}\}$$

The prefix 'T0' is given to the name of each region, to indicate that the 'stationary' (non-accelerating) voice always begins on the notated downbeat. The integer(s) proceeding 'T0' represent the "transpositional operation that derives each copy from the original, expressed as a positive or a negative integer (Cohn, 1992, p. 53).

Piano Phase moves through a full cycle of phase shifting, eventually returning to unison. The principal pattern is played by two pianos in unison for somewhere between 12 and 18 bars. One of the players then accelerates very gradually until they have moved exactly one beat ahead of the second player. The two players lock into the new prolongation region ($T_{0,11}$) for 16 to 24 repetitions of the cycle, after which the process is set in motion again, with one player moving gradually ahead of the other. The process continues through all twelve beats of the cycle, which is completed when the two players return to unison. The material in section B and section C of *Piano Phase* is run through the same phase shifting process. The number of notes in their principal patterns however, is 8 and 4 respectively. Therefore, the number of shifts, and the length of the cyclic process diminishes in each new section.

The phase shifting process does not always satisfy a complete revolution. For example, *Phase Patterns* "begins in rhythmic unison, and alternates progressions (phase shiftings) and prolongations (marked by the introduction of resulting patterns) until the second voice has moved four beats ahead of the first" (Cohn, 1992, p. 153). The series created by the process is $\{T_{0,0}; T_{0,7}; T_{0,6}; T_{0,5}; T_{0,4}\}$. This series indicates that phasing ceases half way through the mod-8 cycle. Rather than returning to unison, the piece finishes when two additional accelerating voices execute the same rhythmic pattern using a different pitch set [02467].

The adaptation of the process in *Violin Phase* is slightly more complicated due to the increased number of participating voices. Like in *Phase Patterns*, the first half of *Violin Phase* begins in unison, then moves through the first four beats of the cycle. Because there are twelve beats in the principle pattern, the series is expressed as $\{T_{0,0}; T_{0,11}; T_{0,10}; T_{0,9}; T_{0,8}\}$. The series unfolds more rapidly in *Violin Phase*, due to the absence of 'resultant patterns' in the opening section. Here, the term 'resultant patterns' refers to the instrumental doubling of a pattern contained within the musical texture.[8] In *Violin Phase*, these patterns extend through the region $T_{0,8}$ signifying the end of the first set of accelerations. The two interlocking voices remain fixed (maintaining the pattern at $T_{0,8}$) in the second half of *Violin Phase*. A third voice mirrors the pattern created by the second, and begins a progression through $T_{0,7}$, $T_{0,6}$ and $T_{0,5}$. The region $T_{0,4}$ marks the second appearance of 'resultant patterns', which continue for the remainder of the composition. The tiered structure of the phase shifting process in *Violin Phase* results in the following series:

$$\{T_{0,0};\ T_{0,11};\ T_{0,10};\ T_{0,9};\ T_{0,8(8)};\ T_{0,8(7)};\ T_{0,8(6)};\ T_{0,8(5)};\ T_{0,8(4)}\}$$

Table 4-1 provides a summary of the structure of the beat cycle in all three compositions. The summary indicates that the phase shifting process in *Phase Patterns* moves half-way through its mod-8 cycle. In *Violin Phase*, the process ends when ends when its "twelve-beat cycle is trisected" (Cohn, 1992, p. 153).

Table 4-1 Summary of symmetric divisions of the beat cycle

Phase Patterns	$T_{0,0}$; $T_{0,7}$; $T_{0,6}$; $T_{0,5}$; $T_{0,4}$
Violin Phase	$T_{0,0}$; $T_{0,11}$; $T_{0,10}$; $T_{0,9}$; $T0_{,8(8)}$; $T0_{,8(7)}$; $T0_{,8(6)}$; $T0_{,8(5)}$; $T0_{,8(4)}$
Piano Phase	A: $T_{0,0}$; $T_{0,11}$; $T_{0,10}$; $T_{0,9}$; $T_{0,8}$; $T_{0,7}$; $T_{0,6}$; $T_{0,5}$; $T_{0,4}$; $T_{0,3}$; $T_{0,2}$; $T_{0,1}$ B: $T_{0,0}$; $T_{0,8}$; $T_{0,7}$; $T_{0,6}$; $T_{0,5}$; $T_{0,4}$; $T_{0,3}$; $T_{0,2}$; $T_{0,1}$ C: $T_{0,0}$; $T_{0,3}$; $T_{0,2}$; $T_{0,1}$

As indicated, the structural progression of *Piano Phase* ends when its 12, 8, and 4 beat cycles have returned to unison. In each composition, the structural motion is characterised by T_{-4}. That is, important transitions occur in four-beat cycles. For example, the structural motion in each section of *Piano Phase* can be expressed as follows:

[8] Resultant patterns are also referred to as 'cellular patterns' in the third section of this chapter, so that they can be easily distinguished from 'resulting patterns'.

Section A: 12

Section B: 12_{-4}

Section C: $12_{-4(-4)}$

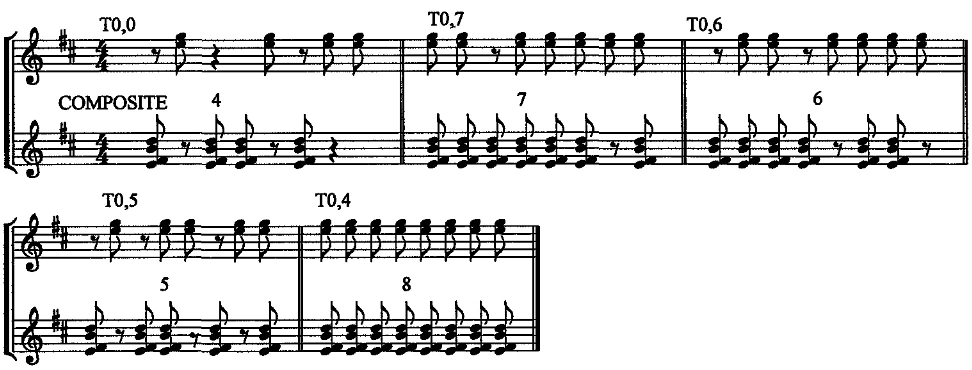
C: Attack-Point Frequencies

Once the phase shifting process is set in motion, new bc sets are formed from the combination of the original set and its transposition in each region. By calculating the attack-point frequency of each prolongation region, it is possible to reveal relationships between the original set and the sets that emerge as a result of phase shifting. The aim is to identify a type of "generic code" that is set in motion by the phasing process, and to consider the extent to which such a code will impact on the listening experience (Cohn, 1992). This is achieved, primarily, by examining the relationship between the frequency of attacks and doubled attacks in each composition.

(i) Attack-point design of Phase Patterns

Figure 4-8 shows the composite patterns produced by the two performers in *Phase Patterns*. Note that in each region, the high and low pitch sets are attacked the same number of times.

Figure 4-8 Prolongation regions in *Phase Patterns*



A further observation is that each region has a unique attack-point frequency. The number of attacks in each region, indicated by the numbers in each bar, form the series {4, 7, 6, 5, 8}. The series moves indirectly from minimum to maximum, and the number of attack-points is not repeated at any stage throughout the progression. According to Cohn (1992), "these properties of maximum variety and progression to a point of saturation are easily audible, and indeed are among the most immediate aspects of the listening experience" (p. 154).

As stated previously, interval class vectors are obtained by subtracting the attack-point frequency in each region from the number of beats in the entire sequence (mod-8 cycle).

Therefore, interval classes for *Phase Patterns* are:

$\{T_{0,0}\} = 4$
$\{T_{0,7}\} = 1$
$\{T_{0,6}\} = 2$
$\{T_{0,5}\} = 3$
$\{T_{0,4}\} = 0$

These figures are interpreted by Cohn as follows:

> The cardinality theorem shows that the properties of the attack-point frequency pattern of *Phase Patterns* - the maximum variety, the path from minimum to maximum culminating in aggregate completion, the indirectness of the path, and even the symmetry - reflect Reich's initial choice of principal rhythmic pattern. (Cohn, 1992, p. 156)

As stated earlier, a necessary condition for achieving maximum variety is the deep-scale property of the primary set. The ic set {4,1,2,3,0} satisfies the deep scale condition, because it does not contain repeated values. In addition, the appearance of the zero in the vector ensures complement relations "at a unique transpositional value, making aggregate completion possible at that interval" (Cohn, 1992, p. 157). In *Phase Patterns*, aggregate completion eventuates in region $T_{0,4}$, where every beat of the mod-8 cycle is articulated (see Figure 4-8).

While Cohn acknowledges that "other paths through *Phase Patterns* are certainly available", he is not referring to alternative patterns which are formed as a result of crossing the point of intersection between registral sets. Rather, he suggests that other paths might be influenced by the fact that "pitch sets that are simultaneously attacked by two instruments may have a slightly different quality than those attacked by only a single instrument, and listeners may be responsive to variations in these qualities" (p. 157). Chapter 5 of the thesis reports two experiments which investigated the role of doubled attacks on listeners' perception of pulse. For this reason, a discussion of doubled attacks, and their relationship to the frequency of overall attack-points, is pursued below.

Table 4-2 demonstrates that the sum of attacks and doubled attacks in *Phase Patterns* is 8, which is equal to the total number of beats per measure.

Table 4-2 Relationship between attacks and doubled attacks in *Phase Patterns*

	$T_{0,0}$	$T_{0,7}$	$T_{0,6}$	$T_{0,5}$	$T_{0,4}$
Attacks	4	7	6	5	8
Doubled attacks	4	1	2	3	0
Sum	8	8	8	8	8

Cohn suggests that the inverse relationship between the number of doubled attacks and the number of total attacks per pitch set, may be susceptible to an alternative perceptual interpretation:

> while the total number of attacks intensifies to a maximum, the number of doubled attacks deintensifies, at the same rate, to zero. A listener exclusively attuned to such relations will thus have a different teleological experience than a listener attuned to variations in attack-point frequency. (Cohn, 1992, p. 157)

It is argued that the presence of doubled attacks, their frequency and progression, will have less of a bearing on a listener's experience than the progression of attack-points in each region. For example, it is doubtful "whether measure 1, where a single organ plays the basic pattern and nothing is doubled, and measure 3, where two organs play the basic pattern and everything is doubled, are heard as maximally dissimilar" (p. 157).

(ii) Attack-point design of Violin Phase

Cohn provides an account of attack-point design for the set [0257] of *Violin Phase*. In this section, I will consider the set formed by the low C# attacks [05], and the set formed by the union of the registral extremes [024579]. Once again, the objective of extending Cohn's analysis, is to test for the presence of linear characteristics. First however, the attack-point design of the set [0257] is reviewed here, to demonstrate how it informs Cohn's argument.

Table 4-3 Attack-points for the set [0257] of *Violin Phase*

Region	Frequency of Attacks
$T_{0,0}$	4
$T_{0,11}$	8
$T_{0,10}$	6
$T_{0,9}$	7
$T_{0,8(8)}$	8
$T_{0,8(7)}$	9
$T_{0,8(6)}$	10
$T_{0,8(5)}$	8
$T_{0,8(4)}$	12

Although the attack-point design of *Violin Phase* is more complicated than that of *Phase Patterns*, they share a number of similarities. For example, the attack-point design in both compositions moves indirectly from minimum to maximum. The number of attack points for the set [0257], shown in Table 4-3, suggests movement toward a goal, with deflections at $T_{0,11}$ and $T_{0,8(5)}$.

The twelve beat-class aggregate at $T_{0,8(4)}$ utilises the maximum number of attack-points in the mod-12 cycle. The appearance of attack points equal to 8 are evenly dispersed throughout the composition at $T_{0,11}$; $T_{0,8(8)}$; and $T_{0,8(5)}$. Although these regions share the same attack-point frequency, identical cardinalities are not apparent in consecutive regions. The entire attack-point series for [0257] is RI invariant at $T_{0,8(8)}$, which is consistent with the design of *Phase Patterns* discussed above.

The first half of *Violin Phase* consists of two voices sounding the principal pattern at different rhythmic transpositions. Attack-point frequencies for the first 5 regions of *Violin Phase* are {4,8,6,7,8}. Interval class vectors for the set [0257] are obtained by subtracting the number of attack-points, from the number of attack-points of the set multiplied by the number of voices. The following series is obtained:

$\{T_{0,0}\} = 4$
$\{T_{0,11}\} = 0$
$\{T_{0,10}\} = 2$
$\{T_{0,9}\} = 1$
$\{T_{0,8}\} = 0$

The treatment of figures becomes more complicated in the second half of *Violin Phase* due to the introduction of a third voice. Cohn (1992) utilises a theorem that "plots the cardinality of the union of three transpositions of a single pattern" (p. 158).

Table 4-4 Cardinality theorem from Cohn (1992)

Source: Cohn, 1992, p. 159

(Union of three Tn - related sets). Q = [0257], x = 0, y = 8, z = decrement from 8 to 4. It should be noted that 3(#Q) = 12. The cardinality is the sum of the last two terms of the equation, subtracted from 12.

x,y,z	ADJEMB ({x,y},Q)	ADJEMB ({y,z},Q)	SUM	12-SUM
0,8,8	0	4	4	8
0,8,7	3	0	3	9
0,8,6	0	2	2	10
0,8,5	3	1	4	8
0,8,4	0	0	0	12

In Table 4-4, the first column indicates the region of the composition, the second and third provide interval classes for {x,y} and {y,z} respectively. The sum is provided in column four, and the total attack-point cardinality in column five. Cohn demonstrates that two characteristics of the attack-point design of *Violin Phase*, its aggregate completion and its symmetry, result from the combinational properties of [0257].

> A combinational tetrachord (in a system of 12 elements) is one which, in union with two of its transpositions, exhausts the aggregate. (Cohn, 1992, p. 159)

The advantage that [0257] has over the other 7 tetrachords is that, apart from [0123], it is the only tetrachord to produce an attack-point design such that no two consecutive regions have identical densities. This is related to the fact that both [0123] and [0257] have deep-scale like tendencies. While, the set [0123] arranges the series in a sequential and predictable way, the [0257] tetrachord generates a more varied attack-point design. Table 4-5 shows the cardinality table for combinational tetrachords which would occur if run through the process in *Violin Phase*:

Table 4-5 Cardinality table for combinational tetrachords

Source: Cohn, 1992, p. 160

prime form	T0,0	T0,11	T0,10	T0,9	T0,8(8)	T0,8(7)	T0,8(6)	T0,8(5)	T0,8(4)
0123	4	5	6	7	8	9	10	11	12
0127	4	6	7	8	8	8	9	10	12
0167	4	6	8	8	8	8	8	10	12
0235	4	7	6	6	8	10	10	9	12
0136	4	7	7	6	8	10	9	9	12
0356	4	7	7	6	8	10	9	9	12
0257	*4*	*8*	*6*	*7*	*8*	*9*	*10*	*8*	*12*
0369	4	8	8	4	8	12	8	8	12

Cohn acknowledges that "this inquiry into variation in the attack-point design of the double-stop fragments represents only one possible path through the piece. Other paths, focusing on attack-point density variations in other basic rhythmic sets of the piece yield less interesting results for this piece..." (p. 163). An analysis of the sets [05] and [025689] is provided below, to test for further evidence of linearity.

Table 4-6 shows the attack-point frequencies and interval classes for the set [05]. Although the attack-point frequencies generated by the [05] set move from minimum to maximum with one deflection at $T_{0,8(5)}$, the range of attack-points is far less significant than the [0257] set. Table 4-6 illustrates that four consecutive regions of the progression {$T_{0,11}$; $T_{0,10}$; $T_{0,9}$; $T_{0,8(8)}$} have identical cardinalities.

Table 4-6 Attack-point frequencies and interval classes for [05]

Region	Frequency of attacks	Interval classes
$T_{0,0}$	2	2
$T_{0,11}$	4	0
$T_{0,10}$	4	0
$T_{0,9}$	4	0
$T_{0,8(8)}$	4	0
$T_{0,8(7)}$	5	1
$T_{0,8(6)}$	6	0
$T_{0,8(5)}$	5	1
$T_{0,8(4)}$	6	0

The figures also demonstrate that the degree of variation of attack-points in the second half of the composition is minimal for the set [05]. Overall, the set does not generate maximum differentiation within the constraints of the process.

Table 4-7 shows the attack-point frequencies and the interval classes for the set [024579]. Once again, the attack-point frequencies do not demonstrate a steady progression toward a foreseeable goal. The figures move indirectly from minimum to maximum with deflections at $T_{0,11}$ and $T_{0,8(5)}$.

The series contains repetitions of attack-point frequencies at irregular intervals. I argue that the section containing doubled resulting patterns, which intercepts the entire series at $T_{0,8(8)}$ for a minimum of 42 bars, would further hinder the perception of linearity in the indirect progression of attack-point frequencies.

Table 4-7 Attack-point frequencies for [024579]

Region	Frequency of attacks	Interval classes
$T_{0,0}$	6	6
$T_{0,11}$	11	1
$T_{0,10}$	8	4
$T_{0,9}$	9	3
$T_{0,8(8)}$	10	2
$T_{0,8(7)}$	11	7
$T_{0,8(6)}$	12	6
$T_{0,8(5)}$	10	7
$T_{0,8(4)}$	12	6

Other characteristics, such as doubling relations, which arise from the union of the original set and its transpositions, are considered below for the sets [05] and [024579]. Once again, the comparison is used to test the generality of Cohn's argument.

Table 4-8 Doubling relations in *Violin Phase* for the low C# [05]

There are 2 attacks per voice per measure: v = number of participating voices; av = number of attacks per voice per measure; ab = total number of attacked beats per measure; db = total number of doubled beats per measure; db = (v x av) - ab.

	First half	Second half
Attacks	2 4 4 4 4	4 5 6 5 6
Doubled attacks	2 0 0 0 0	2 1 0 1 0
Sum	4 4 4 4 4	6 6 6 6 6

Table 4-8 demonstrates an inverse relationship between attacks and doubled attacks per measure for the set [05], in terms of their progression from minimum to maximum or vice versa. Table 4-9 shows the relationship between attacks and doubled attacks for the set [0257].

Table 4-9 Doubling relations in *Violin Phase* for [0257]

There are 4 attacks per voice per measure, therefore: v = 4; v x av = 8 (2 voices, 4 attacks per voice); v x av = 12 (3 voices, 4 attacks per voice)

	First half	Second half
Attacks	4 8 6 7 8	8 9 10 8 12
Doubled attacks	4 0 2 1 0	4 3 2 4 0
Sum	8 8 8 8 8	12 12 12 12 12

Each half of *Violin Phase* shows an indirect decrease in the number of doubled attacks for [0257], offsetting the ascending progression of overall attacks. In this regard, the design displays similarities to *Phase Patterns*.

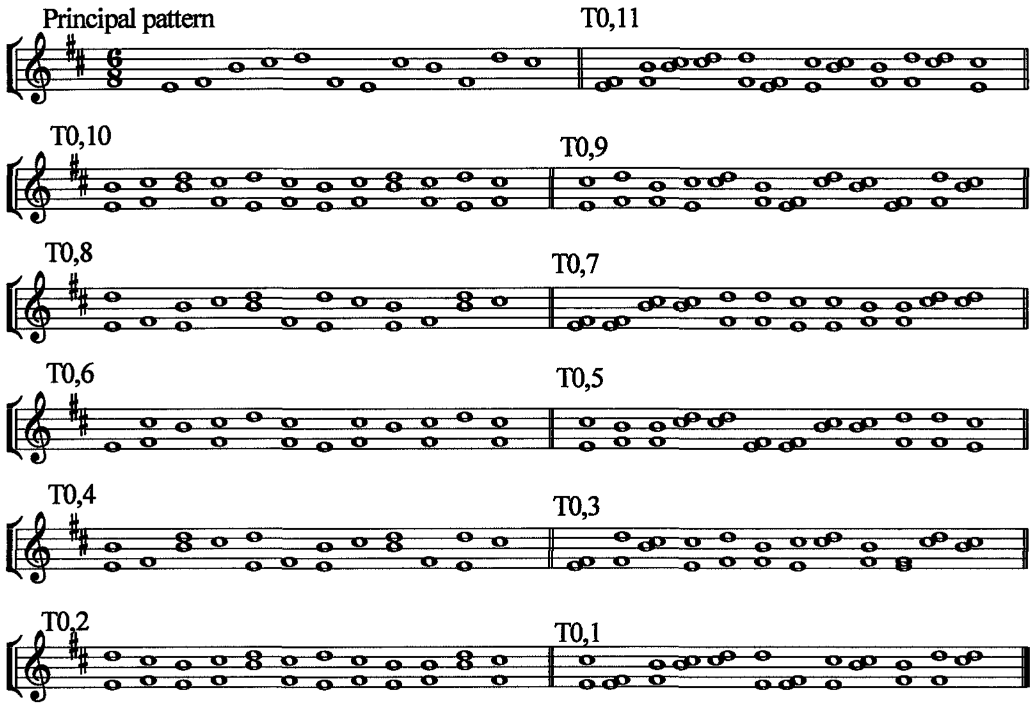
Cohn uses his investigation of attack-point design to suggest that *Violin Phase* and *Phase Patterns* possess teleological qualities. His argument is based on the fact that "the similarity of these designs between the two compositions weakens the possibility that these properties are merely fortuitous" (p. 164). That is, he equates the variety of frequencies offered by these compositions with the composer's concern for "creating maximum possible differentiation within the constraints of the phase shifting process" (p. 164). Cohn also points out that the deflections to the apparent goals resemble a more traditional "nuanced approach to the shaping of temporal experience" (p. 164). I have demonstrated that the figures obtained for the sets [05] and [024579] are not consistent with this argument. I suggest that any aspects of linearity derived from the frequency and dispersion of attacks and doubled attacks may only be perceived if a listener is attuned to a particular set for the entire composition. As will be argued in Chapter 6, this situation is unlikely, due to the range of patterns available which may emerge with or without the listener's volition. The following analysis explores whether or not the progressive internal structures revealed by Cohn are also present in *Piano Phase*.

Through an analysis of *Piano Phase*, I will demonstrate that the frequency and dispersion of attacks and doubled attacks is far less variable than for *Violin Phase*, set [0257], and *Phase Patterns*, suggesting that achieving "maximum differentiation" may not have been Reich's priority in his choice of material to run through the phase shifting process.

(iii) Attack-point design of Piano Phase

Figure 4-9 shows the composite of the two piano parts. The notation reveals that mapping occurs between regions $T_{0,11}$ and $T_{0,1}$; $T_{0,9}$ and $T_{0,3}$; and $T_{0,7}$ and $T_{0,5}$.

Figure 4-9 Composite patterns formed by two players in *Piano Phase*



Attack-point frequencies are obtained by counting the number of attack-points present for each registral set. The frequencies are smaller in number for the lower set in *Piano Phase* due to the cardinality of the original set. Table 4-10 shows the attack point frequencies for both the high and low sets of section A.

Table 4-10 Attack-point frequencies in section A of *Piano Phase*

Region	[01478]	[0125689]
$T_{0,11}$	8	10
$T_{0,10}$	10	12
$T_{0,9}$	8	10
$T_{0,8}$	7	9
$T_{0,7}$	8	10
$T_{0,6}$	8	10
$T_{0,5}$	8	10
$T_{0,4}$	7	9
$T_{0,3}$	8	10
$T_{0,2}$	10	12
$T_{0,1}$	8	10

The parallelism of attack-points for both streams is immediately apparent, as are the *consecutive* regions with identical cardinalities at $T_{0,5}$; $T_{0,6}$; and $T_{0,7}$. Table 4-10 demonstrates that the entire series is retrograde in design, rather than RI invariant as in *Violin Phase* and *Phase Patterns*. Previous analysis showed that the musical material in *Phase Patterns* generates unique attack-point frequencies throughout, and that in *Violin Phase*, the process generates a series where no two consecutive regions have the same attack point frequency. In contrast, *Piano Phase* repeats attack point frequencies, and these repetitions appear consecutively across three phases.

As established, ic vectors are found by subtracting the number of attack-points for each set, from the number of beats in the set multiplied by the number of voices. The interval classes for each set are as follows:

Table 4-11 Interval classes for the principal bc sets of *Piano Phase*

bc set	Interval classes
[01478]	2, 0, 2, 3, 2, 2, 2, 3, 2, 0, 8
[0125689]	4, 2, 4, 5, 4, 4, 4, 5, 4, 2, 4

The sets of figures above *do not* hold the deep scale property because their dyadic subsets (interval classes) are not "distributed such that each dyad class is represented with a unique multiplicity" (Cohn, 1992, p. 152).

The metric-cycles of sections B and C

Before looking at section A of *Piano Phase* in more detail, sections B and C are considered in terms of their metric-cycles and attack-point design.

2nd section: bars 16-26 (mod-8 cycle)

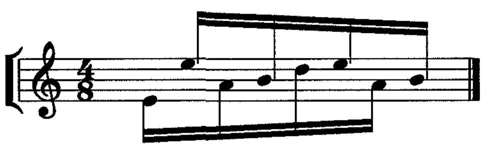
3rd section: bars 27-32 (mod-4 cycle)

The second section of *Piano Phase* introduces a new technique where the two pianos do not play identical melodies. The stationary (repeating) melody has been derived from the principal pattern in section A, however it is adapted to a mod-8 system. As shown in Figure 4-10, the notes of the two melodies show a considerable amount of overlap, making it difficult to hear them independently.

Figure 4-10 Interlocking patterns in Section B of *Piano Phase*

Stationary Pattern

Mobile Pattern



The interval created by the F#4-B4 which featured in Section A of *Piano Phase* is maintained in the stationary pattern in Section B. The A4 introduced in the mobile pattern, however, infiltrates the F#4-B4 interval reducing the potential for composite patterns to segregate clearly into registral groups (see Figure 4-10). For this reason, it is predicted that the variety of possible streams is enhanced due to the introduction of a new set of pitches (the intervals falling well within "ambiguous" regions according to coherence and fission boundaries). The existence of E4 and F#4 is less discrete as a beat class set, due to the close proximity of A4, which has the potential to infiltrate the low stream, or capture the F#4 into an intermediate stream. The combination of contrasting patterns does not permit a clear analysis of bc sets, because the potential resulting patterns are numerous. I argue that pattern perception research can contribute to a better understanding of the range of patterns available in these sections.

Section C of *Piano Phase* returns to the technique of duplicating the same melody in both piano parts. The pattern is reduced to a mod-4 cycle, perhaps derived from the sequence of four ascending notes of the mobile pattern in Section B {A-B-D-E}.

Figure 4-11 Mod-4 cycle in Section C of *Piano Phase*

Once again, the notes are too close together to form distinctive sub-patterns, but this does not mean that individual notes or groups of two notes could not be selectively attended to. This distinction is clarified in the discussion of attention-based processes in the final section of this chapter. The diminution of registral characteristics in each section of *Piano Phase* suggests that, for interesting and variable patterns to result as the piece progresses, primitive processes must be dominated by schema-based attentional ones.

Another issue concerns the capacity of the phase shifting part to detract from the metric stability of the original pattern. The original voice always begins on the notated downbeat. The transpositions that follow however, soon prohibit the downbeats from being perceived as such. As suggested by Epstein (1986), the accents begin to compete for supremacy, and the downbeat is in constant need of reinterpretation.

Returning to section A, the beat class sets formed by composite patterns are considered in more detail. The bc sets shown in Table 4-12 reflect the retrograde design of attack-point frequencies in both sets. Although the cardinality of attack-points for regions $T_{0,5}$; $T_{0,6}$; and $T_{0,7}$ are the same, the beat-class set for $T_{0,6}$ is unique. Note that the [0125689] set, that is, the primary set for the upper stream, returns at the structurally significant regions $T_{0,8}$ and $T_{0,4}$ in the lower stream. This is one example of self-similarity, where bc sets return in different spatial dimensions of the music. Other examples of these types of relations are considered in Section D of the analysis.

Table 4-12 Beat-class sets in section A of *Piano Phase*

Region	bc_1 (lower)	bc_2 (higher)
$T_{0,0}$	[01478]	[0125689]
$T_{0,11}$	[01245789]	[012345789 10]
$T_{0,10}$	[012346789 10]	[0123456789 10 11]
$T_{0,9}$	[01345689]	[012345679 10]
$T_{0,8}$	[0125689]	[01245689 10]
$T_{0,7}$	[01234589]	[012345687]
$T_{0,6}$	[0124678 10]	[012346789 10]
$T_{0,5}$	[01234589]	[0123456789]
$T_{0,4}$	[0125689]	[01245689 10]
$T_{0,3}$	[01345689]	[0123456789 10]
$T_{0,2}$	[012346789 10]	[0123456789 10 11]
$T_{0,1}$	[01245789]	[012345789 10]

Cardinalities of the emergent bc sets

The cardinality of beat-class sets illustrated in Table 4-12 above reflect levels of density for each region. In *Piano Phase*, the attack-point frequencies display fairly consistent levels of density, although I suggest that the perception of density (the number of attack-points) is sensitive to other features of each region, for example, levels of dissonance and consonance.

The density of attack-points in section A increases at $T_{0,10}$ and $T_{0,2}$, and falls marginally at $T_{0,8}$ and $T_{0,4}$. The structural significance of T_{-4} is reinforced by the dispersion of the change in density in these regions. The degree of attack-point variation in *Piano Phase* is not consistent with that of *Phase Patterns* and *Violin Phase.*

Doubling relations in Piano Phase

The relationship between attacks and doubled attacks was found to be inversely proportional in *Violin Phase* and *Phase Patterns.* As shown in Table 4-13 however, there is a significantly different relationship between attacks and doubled attacks in *Piano Phase.*

Table 4-13 Relationship between attacks and doubled attacks for [01478]

	T0,0	T0,11	T0,10	T0,9	T0,8	T0,7	T0,6	T0,5	T0,4	T0,3	T0,2	T0,1
Attacks	5	8	10	8	7	8	8	8	7	8	10	8
Doubled	5	2	0	2	3	2	2	2	3	2	0	2
Sum	10	10	10	10	10	10	10	10	10	10	10	10

Rather than displaying direction toward a goal which spans from minimum to maximum, or vice versa, attacks and doubled attacks show comparatively little variation, and contain several consecutive regions which have identical cardinalities. Similarly, the relationship between attacks and doubled attacks for the higher set [0125689] differs significantly from that found in *Violin Phase* and *Phase Patterns* (Table 4-14). There is no steady progression toward a goal in either series, and the variation of attack-points is minimal, suggesting that it is unlikely to impact strongly on listeners sense of structural motion.

Table 4-14 Relationship between attacks and doubled attacks for [0125689]

	T0,0	T0,11	T0,10	T0,9	T0,8	T0,7	T0,6	T0,5	T0,4	T0,3	T0,2	T0,1
Attacks	7	10	12	10	9	10	10	10	9	10	12	10
Doubled	7	4	2	4	5	4	4	4	5	4	2	4
Sum	14	14	14	14	14	14	14	14	14	14	14	14

To take the figures for doubled attacks one step further, Table 4-15 demonstrates composite bc sets for each region in order to highlight the characteristics of their dispersion.

Regions marked with an asterisk are transpositionally invariant [TINV] sets, that is, they are capable of mapping themselves at some non-zero transposition. Diagonal arrows point out the emergence of the low primary set [01478] as a set of doubled attacks at $T_{0,8}$ and $T_{0,4}$ in the [0125689] stream, once again, highlighting the structural significance of T_{-4}. The beat class sets for doubled attacks demonstrate a retrograde design for the entire series.

Table 4-15 Beat-class sets for doubled attacks in *Piano Phase*

	low stream	high stream
$T_{0,0}$	[01478]	[0125689]
$T_{0,11}$	[05]	[0158]
$T_{0,10}$	-	[06]*
$T_{0,9}$	[03]	[0347]
$T_{0,8}$*	[048]	[01478]
$T_{0,7}$	[01]	[0145]
$T_{0,6}$*	[06]	[0268]*
$T_{0,5}$	[01]	[0145]
$T_{0,4}$*	[048]	[01478]
$T_{0,3}$	[03]	[0347]
$T_{0,2}$	-	[06]*
$T_{0,1}$	[05]	[0158]

Summary

Section C of the analysis suggests that "maximum differentiation within the constraints of the phase shifting process" was not Reich's primary concern when choosing the musical material for *Piano Phase*. The linear progressions identified by Cohn were found in the principal set of *Phase Patterns*, and one of the sets in *Violin Phase*. I have argued that such progressions may be offset by the characteristics of the other beat class sets which were not discussed by Cohn. I have also demonstrated that the additional sets of *Violin Phase*, [05] and [024579], do not display progressive features as strongly. In addition, I have argued that the large sections of instrumental doubling (resultant patterns) in *Violin Phase* and *Phase Patterns*, which interrupt the phase shifting process, potentially obstruct the series of attack-points from being perceived as a progressive series. Before discussing how these findings contribute to a reassessment of temporality in Reich's music, equivalence and complement relations are examined for further comparison.

D: Equivalence and Complement Relations

Complement relations between several regions of *Violin Phase* have been identified by Cohn (1992). He acknowledges that complement relations have been used by pitch-class theorists to reveal "their appearance in ...works of the atonal repertory" (p. 167), but states that their presence is not psycho-acoustically grounded. He argues however, that complement relations in beat classes are more salient than those of pitch classes. With regard to the example shown below, Cohn suggests that complement relations in Reich's *Violin Phase* are perceptually significant because of the fact that "the smaller of the complementary sets contains no interval class 1" (p. 168). He asserts that the complement relation shown below "implies the presence of a readily hearable equivalence relation" (p. 168).

Figure 4-12 Complement relation in *Violin Phase* [0257]

According to Cohn, notes of the [0257] set preceded by a rest are more salient than notes preceded by other notes, therefore, the equivalence of the pattern of attacks in both regions is strengthened. He argues that complement relations "give further shape to the form of the piece, by insuring that it does not merely unfold like carpet, but refolds upon itself, creating a contour of some formal complexity" (p. 168).

Similar relationships can be found in *Piano Phase* between the principal pattern and its first permutation. Both the higher and lower sets of the principal pattern are strongly reflected in phase 1 ($T_{0,11}$) as shown in Figure 4-13. Due to the retrograde design of *Piano Phase*, this equivalence returns in $T_{0,1}$ before the final phase transition which returns the two parts to unison. Although the above example does not represent exact equivalence, it could be argued that the presence of doubled attacks in the high set of $T_{0,11}$ strengthens the complement relationship between the two regions.

Figure 4-13 Complement relation in *Piano Phase*

Summary

The relationship between the presence of equivalence and complement relations and the temporal nature of the composition can be interpreted in two ways. Cohn argues that these relationships contribute to the subtle shaping of time. On the contrary, I argue that pattern *saturation*, caused by inclusion and complement relations, could account for the impression of stasis often experienced by listeners of Reich's music. Consistency and self-similarity contribute to the "vertical" argument, which claims that the lack of progression, in the traditional sense, prohibits linear relationships from being formed.

<u>E: Critical, Stylistic, and Aesthetic Implications</u>

The analysis provided above, and its comparison with Cohn's findings, returns the discussion to Reich's approach to temporality in these works. Cohn's application of set theory to *Violin Phase* and *Phase Pattern* can be viewed as a response to Gregory

Sandow's comment that "if we want to understand minimalist music we need a genuine analysis" (p. 168). Cohn challenges existing commentary on Reich's phase shifting music which "focuses on extended use of repetition as a prolongational device", which he claims "ignores the progressive context in which these prolongations occur" (p. 169). In particular, Cohn refers to the use of canons and combinational tetrachords, associative set relations, and "maximal variety and integration in the context of rigorous pre-compositional constraints..." (p. 171).

Cohn asserts that the phase shifting process itself falls in line with formal beginnings and endings, raising a further contradiction to the notion of verticality applied to Reich's early works. This is reinforced in his comment that "music which progresses toward its ultimate state of saturation in a systematic fashion has sequential order, motion, progression, and climax" (p. 169). The analysis of *Piano Phase* provided above revealed that the structure did not progress toward "an ultimate state of saturation" in the same way as the other two phase shifting compositions. Therefore, this argument cannot be extended to all three works. In addition, as will be shown in the final section of this chapter, the notion of sequential order and motion is highly ambiguous in light of the segregating characteristics of the beat class sets identified in the analysis.

Some explanation of the paradox between "timelessness" and the application of a linear process is provided by Kramer:

> In practice, much vertical music retains vestiges of linearity, that can be analyzed both for themselves and in relation to work's overriding nonlinearity. This is particularly true of process compositions..., which move at even rates toward foreseeable goals. Such works are nonlinear because they are not hierarchic, and because their motion results from unchanging global principles. Their motion is so evenly paced and so predictable that it is not perceived as progression... Because there are no (important) deviations from the music's predictable course, listening to a process composition can be a vertical time experience. (Kramer, p. 389)

Cohn argues that, in light of this comment, *Violin Phase* and *Phase Patterns* do not warrant the "vertical" label. He asserts that their "motion is neither evenly paced nor predictable (from a listener's point of view)" (p. 169). On several occasions, Cohn uses the results of his analysis to counteract claims made by the composer himself. For example, he draws on parallels between the characteristics of Reich's musical material and compositions born out of the Second Viennese school, "despite Reich's pains, early in his career, to distance himself from their progeny" (p. 171). He questions Reich's intentions once again by drawing attention to the composer's comment that he is not aware of any secrets of structure that the audience cannot hear. Cohn asserts that, in view of his results, "it is reasonable to assume that the composer of *Violin Phase* was in some sense "privy to" something unavailable to "just anyone," in spite of his protestations to the contrary" (p. 170).

Rather than seeking out ways to question the intentions of the composer, it seems to me more beneficial, and less problematic, to reveal aspects of the music that complement the composer's written intent. In the remainder of the thesis, this is achieved through a perceptual analysis which seeks to investigate the relationship between the internal structures revealed by Cohn, and the perceptual reality of these structures which contribute to the overall temporality of the music. This approach is spurred by the knowledge that Reich intended perceptual ambiguity on a number of levels within this music.

Theoretical Evaluation: The Role of Stream Segregation

Introduction

Throughout this chapter, I have suggested that the perceptibility of beat class sets is not necessarily determined by the registral characteristics of the principal patterns. I have argued that the ambiguity of resulting patterns in Reich's music requires a more thorough investigation into the perceptual characteristics of the principal patterns, in order to determine their behaviour under transformation. The purpose of such an inquiry is to consider how formal analytical procedures can be supplemented by perceptual analysis, and inform an understanding of pattern perception and temporality in this music.

For the sake of clarity, the structure of this section reflects that of the literature review in Chapter 3, which was organised according to factors contributing to the segregation of auditory streams. Under each of these headings, it is demonstrated that Reich's choice of musical material, in combination with specific performance instructions, necessarily leads to an ambiguous outcome in terms of the perception of patterns. The unpredictability of resulting patterns also stems from the nature of the listening mode. Therefore, the following section also examines how resulting patterns might differ according to active and passive listening by considering the role of primitive and schema-based segregation processes. As such, it provides the basis for a theoretical model of stream segregation in Reich's early works, which underlies the empirical investigation reported in the following chapters. In addition, it covers aspects of the phase-shifting works, such as acceleration regions and regions of instrumental doubling, that are beyond the scope of beat-class analysis.

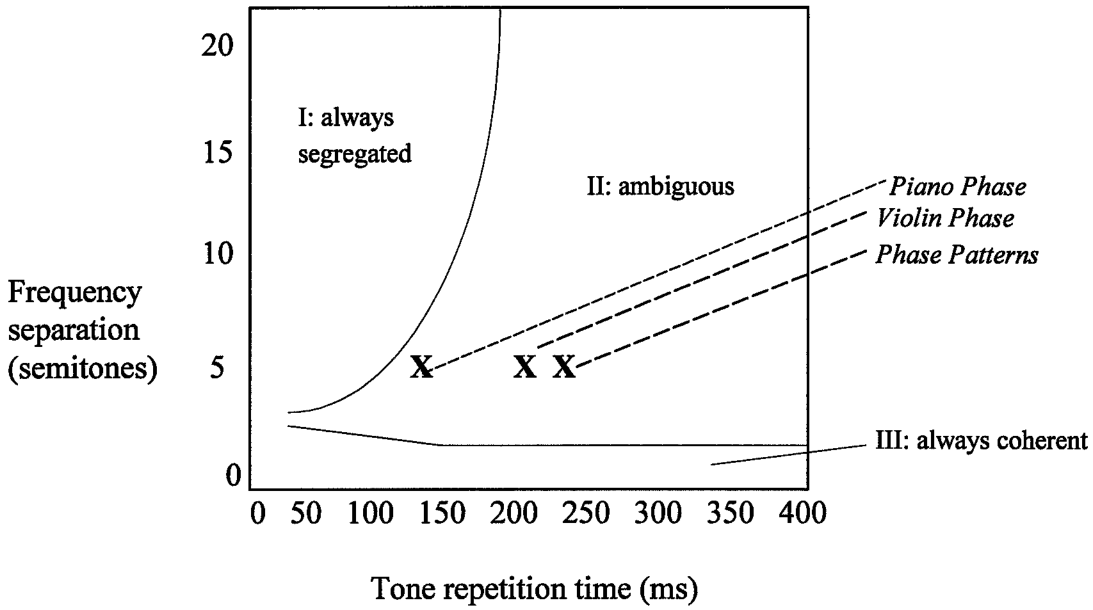
Pitch proximity and pattern rate

The first clue to the significance of perceptual processes in Reich's early works is revealed by the fact that the actual sound sources producing the principal patterns are not represented by resulting percepts. That is, the material presents the illusion that resulting patterns are generated by a discrete sound source. Sequences susceptible to such illusion are created frequently by experimental psychologists to observe perceptual thresholds. As recognised by Bregman (1988), such sequences are not representative of everyday sounds, because our perceptual system must be capable of accurately identifying the source of incoming auditory stimuli. As highlighted in the introduction to the thesis, composers have intuitively exploited such effects in an attempt to challenge traditional notions of temporality. Reich's choice of musical material to be run through the phase shifting process, prohibits the listener from distinguishing sound sources accurately.

I propose that by mapping the intervallic structure of all three principal patterns onto van Noorden's graph of coherence and fission thresholds, it is possible to predict the nature of resulting patterns in Reich's music. The intention is to assess whether or not the musical material is capable of generating resulting patterns that cross registral sets. The specified tempo for each of these compositions allows an assessment of the stream forming potential of the pitch material. Note that the mappings in Figure 4-14 only represent approximations, due to existing evidence that a range of other factors, such as the influence of complex tones, have a bearing on streaming thresholds. Nevertheless, these approximations invoke a more thorough investigation into the stream forming potential of the material chosen by Reich.

Figure 4-14 Mapping pitch and tempo parameters onto van Noorden's (1975) temporal coherence and fission boundaries.

Source: Adapted from Wegner, 1993, p. 211



Van Noorden (1975) demonstrated that at high pattern rates, sequences with large pitch differences have the potential to split perceptually into auditory streams. Reich's compositions have been plotted onto the map according to the largest intervals in their principal patterns:

IOI = 139 ms (dotted crotchet = 72); 5 semitones for *Piano Phase*: F#$_4$ - B$_4$

IOI = 238 ms (crotchet = 176); 5 semitones for *Phase Patterns*: F#$_4$ - B$_4$

IOI = 208 ms (crotchet = 144); 5 semitones for *Violin Phase*: C#$_4$ - F#$_4$, and B$_4$ - E$_5$

Although the largest interval in all three compositions is 5 semitones, the specified tempos distinguish their position on van Noorden's chart. All three compositions fall within the ambiguous region (region II). According to the conditions of van Noorden's experiment, resulting percepts in this region depended on the "attentional set" of the listener. This suggests that the resulting patterns formed by the musical material in Reich's phase shifting compositions are not restricted to the beat-class sets identified by Richard Cohn. Although I agree that the registral characteristics of constituent elements form significant beat-class sets in Reich's early works, these findings demonstrate that the chosen pattern rate and pitch material ensure their perceptual volatility.

According to van Noorden's graph, the tempo, or the largest interval in the primary pattern of *Piano Phase* would have to be increased to induce compulsory segregation. Such a conclusion would not generate the range of patterns currently available. Rather, the combination of musical material and tempo results in an ambiguous percept that may alternate between high patterns, low patterns, or patterns comprising notes from both streams. Perhaps not coincidentally, the largest interval distance in all three compositions is a perfect fourth (5 semitones). The similarity between Reich's choice of musical material and the intervallic structure common to Bugandan xylophone music is notable. As mentioned in Chapter 3, Kubrik (1969) stated that the "predominant use [of the Kiganda-fourth] as an interlocking interval guarantees the appearance of this audio-psychological phenomenon... Fourths interlocking greatly favours hearing at two or three pitch levels" (p. 35). In addition to van Noorden's research, this observation has since been confirmed by studies such as Bregman and Campbell (1971) and Anstis and Saida (1985). Another relevant finding was that of Bregman and Rudnicky (1975), who provided evidence of a "mutual exclusion" property of streams, which states that:

> when a sound is incorporated into one stream, it tends to be unavailable to a second stream. This is the property of "belongingness" referred to by Gestalt psychology: An element cannot be both part of a figure and part of a ground at the same time. (Bregman & Rudnicky, 1975, p. 267)

For example, the intermediate note in *Piano Phase*, 'b', may attach itself to either a high or low stream, but its inclusion is exclusive to one or the other. The visual figure/ground phenomenon is analogous to Reich's music in the condition where the ground is a potential figure in its own right, rather than merely serving as a background.

In relation to *Piano Phase*, Reich states that "the piece may be played an octave lower than written, when played on marimbas" (directions for performance). Literature on stream segregation provides no evidence to suggest that streaming thresholds are sensitive to registral transposition, where the intervallic structure is essentially the same. If this were the case, Reich may not have offered this alternative.

There are a range of other factors which significantly influence the stream forming potential of principal patterns. It will be demonstrated, however, that the conditions underlying this music favour the ambiguous stream forming capacity demonstrated by the mapping of intervals in Figure 4-14.

Sequential and Spectral Organisation: Synchronicity

Cohn's set theory analysis is based on the assumption that the registral streams in each phase are equally salient. Such an assumption would be necessary in order to conclude that linear progressions in this music act as strong temporal forces. Research into sequential and spectral organisation, however, suggests that the competition between the vertical and horizontal components of the music will compete for primacy, and as a result, vertical (simultaneous) components may reduce the salience (combining power) of sequential patterns. Therefore, the segregating potential of principal patterns does not exclusively determine its behaviour under transformation. This will be demonstrated by Experiments 2A and 2B, reported in Chapter 6.

Bregman and Pinker (1978) described the alternation of a single tone with a complex tone consisting of two notes, as an "inherently ambiguous event" (p. 29). They demonstrated that in such a sequence, either sequential or spectral organisation is possible, but the likelihood of each depended on pitch proximity and synchronicity. When simultaneous events have identical onsets and offsets, spectral grouping is favoured. Once again, this suggests that resulting patterns will not be restricted to registral sets. Rather it increases the competition between vertical and horizontal components, and ensures that a range of alternative percepts will be available to the listener. This point draws our attention to the difference between live and recorded (taped) performances. Reich addresses this issue in the following comment:

> Looking back on the tape pieces that preceded *Piano Phase* I see that they were, on the one hand, realisations of an idea that was indigenous to machines, and on the other hand, the gateway to some instrumental music I would never have come to by listening to any other Western... music. The question may then arise as to what it is like to imitate a machine while playing live music. (Reich, 1974, p. 53)

Explicit in this comment, is the intention that "mechanical" playing should be maintained in live performances of Reich's phase shifting music. In this sense, resulting patterns are born out of strict adherence to synchronicity. Once again, this instruction secures the ambiguity of resulting patterns. Rather than being influenced by performer interpretation, resulting patterns emerge out of undifferentiated parameters which are open to interpretation by the listener. It could be argued that slight irregularities common to live performance may influence resulting patterns according the principle of synchronicity, although it is not likely that performers would stray significantly enough from the strict, mechanical playing required. This is reinforced in the instruction to performers which specifies that after the second piano gradually fades in, the performers are given 12 to 18 bars to get "into a comfortable and stable unison", before the first acceleration begins. The principle of synchronicity has a much more profound effect on the segregation of streams in the acceleration regions of Reich's music. These regions are defined by the gradual separation of a pattern from its duplicate. The instruction to performers is to accelerate "very slightly".

The principle of synchronicity predicts that segregation between registral sets in acceleration regions will be more significant than in prolongation regions. The gradual accelerating process may not immediately favour registral streams, but as the acceleration continues and one pattern moves a significant distance ahead of the other, such groupings will be favoured.

Repetition and the cumulative effect

Research into auditory stream segregation has shown that streaming increases during the course of listening (Anstis and Saida, 1985; Bregman, 1978b). The finding that listeners demonstrated a long-term trend toward hearing the sequence as segregated, can be considered in light of Reich's phase shifting music. For example, the continuous repetition in these works suggests that primitive segregation processes will favour registral sets. The nature of pitch material and tempo in these works, however, suggests that listeners will not be restricted to registral patterns (as a result of schema-based processes).

> The number of repeats in each bar is not fixed but may vary more or less within the limits appearing at each bar. Generally speaking a number of repeats more than the minimum and less that the maximum should be aimed for. The point throughout, however, is not to count repeats, but to listen to the two voice relationship and as you hear it clearly and have absorbed it, move on to the next bar. (directions for performance)

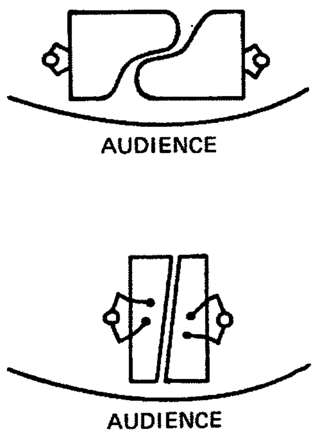
The performance instructions above apply to all three works. The instructions provided by Reich to move on to the next bar once "the two voice relationship has been absorbed", suggests an intuitive awareness of the cumulative effect described by Bregman (1978b). Although the number of repetitions is left to the discretion of the performer, the minimum number of repetitions of the cycle never extends below four. This ensures that the process of stream segregation has enough time to partition the prolongation regions into registral sets. Bregman (1978b) demonstrated that streaming can be "reduced by the presence and length of embedded silences" (Bregman, 1990, p. 128). The lack of silences in these works does not allow the process to revert back to its unbiased state. Phase shifting in these examples is a continuous process which would allow the primitive segregating mechanism to strengthen with time.

Another consideration is whether or not the resulting patterns might be more restricted to the two-voice texture for performers, because their attention is divided between playing the notes, keeping strict time, and listening to the patterns so that they know when to move on. For listeners however, more processing time (attention) can be devoted to 'finding' other patterns within the texture.

Spatial location

In this section, the contribution of spatial location to the ambiguity of resulting patterns will be discussed in terms of performers seating arrangements, and specifications regarding audio equipment.

Figure 4-15 Arrangement of two pianos or marimbas in *Piano Phase*

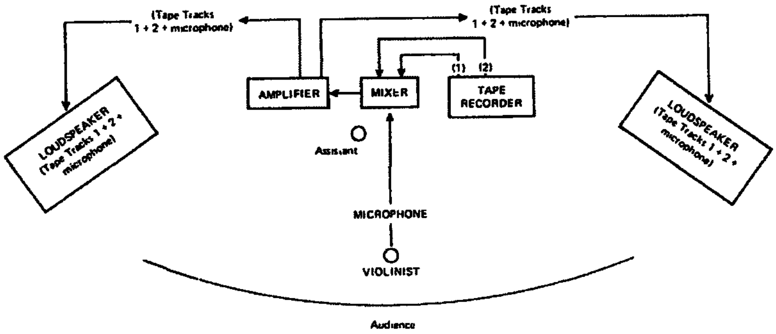


The spatial proximity of performers shown in Figure 4-15 reflects the interlocking structure of principal patterns. The position of the instruments in relation to the audience promotes perceptual confusion, making it difficult to identify the sound source responsible for the patterns that emerge. This confusion is predicted by van Noorden (1975), who demonstrated that the alternation of pitches was not perceived in a sequence when the two pitches were presented to different ears, and that the temporal relations between tones in opposite ears was weak. As demonstrated by Deutch (1975) however, such an illusion can be strengthened or weakened by other factors such as pitch proximity. I argue that in light of pitch material, the spatial arrangement of performers in Reich's music is crucial for the generation of resulting patterns, and that wider spacing would certainly be capable of freezing the play of the system.

One option for a performance of *Violin Phase* is to use one live violinist and three pre-recorded tracks. The recorded tracks are mixed onto a single tape. Using this combination, Reich specifies that the "amplifier should be switched into mono so that both tracks of tape plus the amplified violin will be fed to both loud speakers" (directions for performance). Once again, this ensures the emergence of resulting patterns, and reduces the possibility that patterns will be organised according to discrete sound sources. Similarly, Reich states that if four live violinists participate in the composition, "they should stand or sit close to each other and the audience" (directions for performance).

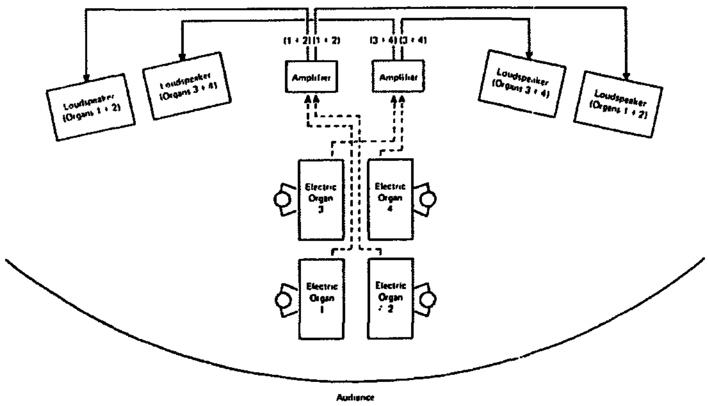
> If the piece is played by one violinist and tape the violinist should stand near the front edge of the stage with a microphone placed 2-4 inches from the 'f-hole' of the violin. The assistant should sit well behind the violinist, but should be able to see and hear the violinist... (directions for performance)

Figure 4-16 Arrangement of violinist and pre-recorded tape in *Violin Phase*



The position of the loudspeakers in *Phase Patterns* shown in Figure 4-17 is also influential. In order to maintain perceptual ambiguity, the loudspeakers are positioned equally in relation to the audience and the live violinist.

Figure 4-17 Arrangement of electronic organs, amplifiers and loudspeakers for *Phase Patterns*



Reich's specification of spatial location in performance is reminiscent of much African music built on interlocking patterns. For example, in relation to Bugandan xylophone music, Wegner (1993) states that:

> proximity is expressed in the close spacing of the three amadinda musicians around one instrument. The physical closeness of the performers does not support the process of clarifying the (played) musical structure of a xylophone piece. On the contrary: as far as the two musicians are concerned..., close spacing makes the identification of the two "sound sources" (musicians) impossible in favour of the emergence of new inherent percepts.
> (Wegner, 1993, p. 209)

Dowling and Harwood (1986) suggest that in Western music, instruments, or instrumental ensembles, are often significantly spaced apart, so that their arrangement is capable of reflecting musical structures. In Reich's phase shifting works, and examples of African music such as that referred to above however, the close proximity of performers "belongs to a strategy of deliberate perceptual camouflage"

(Wegner, 1993, p. 209). Elements of Reich's phase shifting music which resemble certain types of African music include the intervallic configuration of interlocking structures, strict synchronicity, homogeneous timbres, and the spatial proximity of performers.

Continuity and Trajectory

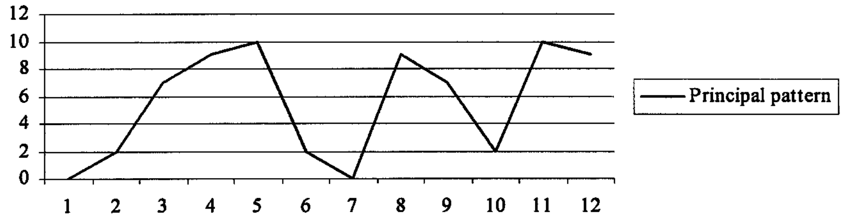
The principles of continuity and trajectory are related in the sense that they both refer to aspects of directionality. As stated in Chapter 3, Bregman and Dannenbring (1973) investigated how the presence of frequency glides contributed to listeners' ability to form auditory streams. Their experiment revealed that subjects were able to judge the order of tones more successfully in sequences containing frequency glides, because sequences were perceived as coherent. In the "discrete" condition, however, the ability of subjects to judge the order of tones was hindered by the fact that the sequence tended to divide perceptually into two separate streams. Such conditions can be likened to features of articulation in music. In all of Reich's instrumental phase shifting compositions, the notes of the principal patterns are to be played relatively detached. Reich specifies 'non legato' at the beginning of *Piano Phase*. In addition, consecutive notes in the patterns are always played by different hands, creating a more disjointed effect. Similarly, bowing marks in *Violin Phase* specify a change of bow direction in each note of the principal pattern. Once again, these specifications for performance ensure the emergence of resulting patterns.

A later study by Tougas and Bregman (1985) found that the "principle of grouping tones by their frequency proximity", dominated over the "principle of grouping tones that follow a smooth trajectory" (p. 788). This was achieved by asking listeners to rate the clarity of target patterns when combined with other distractor tones in a comparison. Listeners' rating responses were taken as an index of stream formation. The results confirmed that the trajectory-based target patterns were more difficult to isolate as discrete perceptual units. Linear representations of the primary pattern and the first 6 regions of *Piano Phase* are provided below, so that the points of intersection formed by the transposition of the principal pattern can be observed.

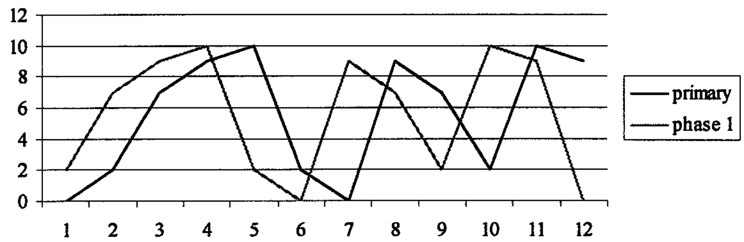
Figure 4-18 Trajectories formed by the interlocking patterns in each region of *Piano Phase*

Numbers on the vertical axis indicate the pitch interval between each note of the cycle (in semitones), and numbers on the horizontal axis indicate each beat of the 12-beat cycle.

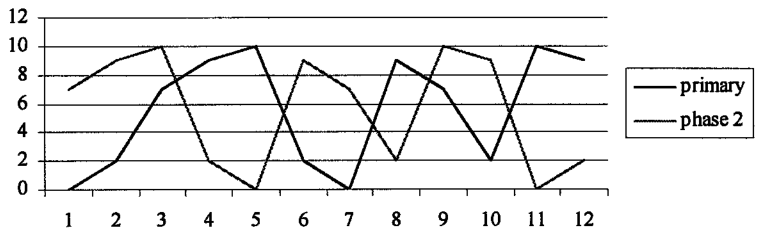
$T_{0,0}$



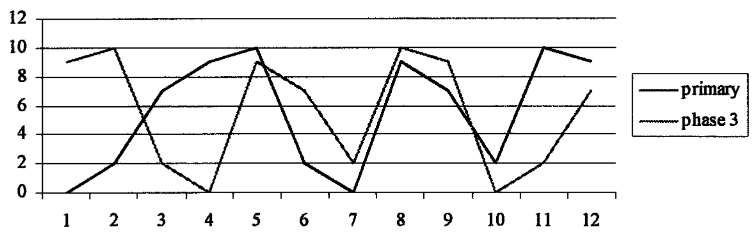
$T_{0,11}$



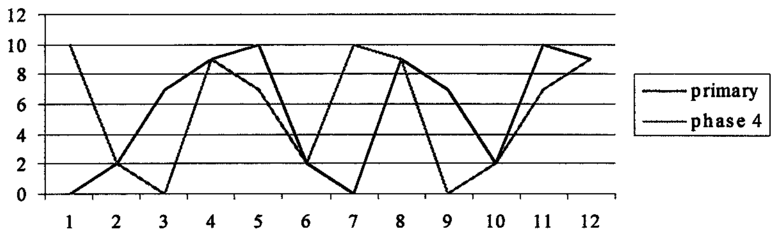
$T_{0,10}$



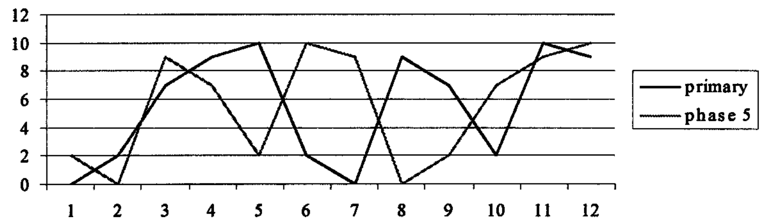
$T_{0,9}$



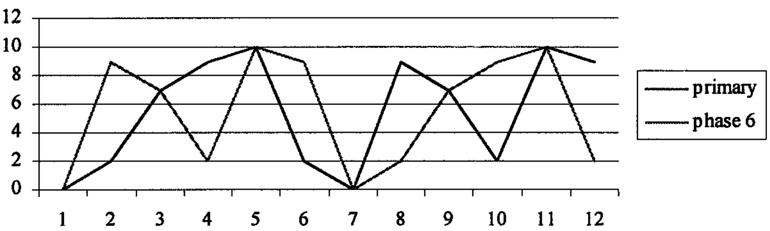
T0,8



T0,7



T0,6



In Chapter 6, the characteristics of the trajectory in each of these regions, shown in Figure 4-18, is considered in terms of how clearly each region separates into registral patterns. That is, does the "principle of grouping tones by their frequency proximity" dominate over the "principle of grouping tones that follow a smooth trajectory" (Tougas & Bregman, 1985, p. 788). As suggested by Epstein, the nature of the two voice texture changes throughout the work. At times the texture is strictly polyphonic, while during other phases the lower voice supports the higher voice homophonically. Occasionally the two voices share the same rhythmic pattern, but do not easily separate.

Timbre and Loudness

As stated previously, the presence of interlocking structures with homogeneous timbres in Reich's music can be compared with musical practices common to certain East and Central Africa. It is argued that the nature of resulting patterns would be significantly different if the principal patterns were played on instruments with distinctly different timbres. Several studies (Warren, Obusek, Ackroff & Warren, 1969; McNally & Handel, 1977; Wessel, 1979; Smith, Hausfield, Power & Gorta, 1982) have demonstrated that "sounds with grossly different timbres resist being assigned to the same stream" (Bregman, 1990, p. 94). Only one of these studies (Wessel, 1979) considered the contribution of individual components of timbre. For example, Wessel showed that when the difference in brightness between the two tones of an alternating pattern was increased, a sequence was less likely to be perceived as coherent. In relation to *Piano Phase*, Reich states that "when two pianos are used they should be as identical as possible. The lids should both be open or removed". Similarly, when "two marimbas are used they should be as identical as possible. Soft rubber mallets are suggested" (directions for performance). Once again, the conditions for performance specified by Reich reflect his concern for ensuring a range of resulting patterns.

Similar concerns are reflected in directions specific to loudness. In *Violin Phase*, Reich provides explicit instructions regarding how the pre-recording of the tape should be accomplished, plus additional information about the stereo tape recorder, microphone, mixer, stereo amplifier and two loudspeakers. A single microphone is used to amplify the live violinist. Reich states that it is "necessary to amplify the violin in order that it match the timbre as well as the volume of the tape". Later however, he states that "the sound of the live violin should be slightly louder" (directions for performance). This instruction is specific to regions in which the live violinist illuminates (brings to the fore) 'resultant patterns' in this composition over the top of the already segregated texture of the pre-recorded parts. When the live violinist plays the accelerations, for example, from $T_{0,0}$ to $T_{0,8(8)}$, the dynamic marking after fading in is *mf*, which is the same dynamic specified for existing parts. When the 'resultant patterns' are introduced however, the dynamic marking is *f*, while the interlocking parts remain set at *mf*.

Similarly, the instruction for *Phase Patterns* is as follows:

> The volume and timbre of organs one and two should be identical, but that of organs three and four from bar 57 may be slightly louder and/or brighter so that resulting patterns [formed by instrumental doubling] can be clearly heard. After bar 57 to the end, organs 3 and 4 should arrange their stops so that they exactly match the volume and timbre of organs one and two. Four identical organs should be used, choosing stops that produce a clear tone without shrill high frequencies and with no vibrato whatsoever. (directions for performance)

There are several important suggestions contained within this instruction. Specifications for timbre, loudness, and the avoidance of vibrato and high frequencies all ensure that the resulting percepts are *not* influenced or dictated by subtleties in performance. I have already demonstrated that homogenous timbre and loudness contribute to the 'free play' of the system. Research in auditory scene analysis has also provided evidence for the binding capacity of tones containing a similar distribution of partials. By instructing that the tone is consistent for all instruments in this piece, Reich ensures that resulting patterns will be derived from a combination of the notes of all players. That is, the chance that resulting patterns will be grouped according to a single instrument is minimised.

Primitive and Schema-Driven Organisation in Reich's Music

This section considers the role of primitive and schema-based segregation processes in the perception and experience of Reich's phase shifting music. Such a discussion is prompted by the superimposition of musical parameters onto van Noorden's fission and coherence thresholds (see Figure 4-14). The intervallic structure of all three compositions, in combination with pattern rate, suggests that ambiguous percepts will result. Sequences falling within the ambiguous region are dependent of the "attentional set" of the listener. The following hypotheses are postulated about the two types of processes in this music:

1. Primitive segregation favours registral grouping in these works, however, the pitch structure and pattern rate in each case is not extreme enough to induce compulsory segregation. Primitive segregation is *more* active in acceleration regions, due to the random nature of tones,
2. By deconstructing, or eliminating a stable centre, Reich has created a system in which schema-based organisational processes come into play. These processes are *less* prevalent in acceleration regions,
3. The presence of primitive and schema-based processes throughout this music is sensitive to active and passive listening modes,
4. In regions where "solo" patterns are introduced over the top of interlocking structures, the relationship between the two processes becomes clearer.
   (a) cellular patterns which cross registral streams will generate the effect of 'looming up' out of the musical texture. Such patterns will be difficult to hold in attention when they cease being 'pointed out', because primitive processes are active in partitioning registral streams.
   (b) *cellular* patterns contained within registral streams do not endorse this effect as strongly, and these patterns can be held in attention for much longer after they fade out (due to a selection process which is made easier by the presence of the primitive segregation process)

Support for these hypotheses is provided in the following discussion, which analyses cellular (resultant) patterns in detail, and considers the role of rhythmic complexity in the segregation of streams according to Jones' rhythmic theory of attention. The acceleration regions, which have been given little attention in previous analyses, are compared with prolongation regions in terms of the interaction between the two types of processes.

Dowling (1973) revealed the presence of two different levels of input processing, which are described as "musical" and "pre-musical". In his study, schema driven processes were shown to override primitive processes when listeners were told which melody they had to extract. Without this information however, they were not able to recognise the familiar melodies, "failing to apply existing schemata because the preattentive process of auditory streaming proved to be dominant" (Wegner, 1993, p. 217). The distinction is articulated further in the comment that:

> [The schema based process]... may overcome the primitive process if there is strong acoustic evidence for this. Although the primitive process partitions the sensory evidence, the schema-driven, attention-based scene analysis *selects* from the evidence without parsing it. While the schema-governed process is applicable only to familiar sound patterns, percipients have to rely upon "primitive auditory scene analysis" in connection with unfamiliar sound patterns. (Wegner, 1993, p. 216)

Although psychological findings provide evidence for the concept of resulting patterns in Reich's music, it could be argued that we are comparing something that should not be compared. That is, "percepts on the pre-musical level (streams) with those on the musical level (inherent patterns) - because the latter are described as culturally meaningful" (Wegner, 1993, p. 216). This concern is further expressed in the following comment:

> On the musical level, expectancy and attention are powerful percept-shaping factors. While attention is "guided by knowledge structures developed in our experience of the world" (Dowling and Harwood 1986: 124-5), the "pre-musical" phenomenon of pitch streaming works on a content-free basis. The latter can be helped or hindered by acquired knowledge about music. (Sloboda, 1985, p. 161)

This comment raises an important point about how differently Reich's music is perceived by musicians and non-musicians. For example, will non-musicians' experience of resulting patterns be more restricted to registral streams (caused by primitive partitioning) than musicians', who presumably have developed stronger musical schemas. This question is incorporated into the design of the Experiments 2A and 2B, reported in Chapter 6.

Cellular patterns

One way of exploring the relationship between primitive and attention-based processes of organisation is to isolate the sections in *Violin Phase* and *Phase Patterns* that contain solo melodies derived from composite patterns. By 'pointing out' patterns that exist within the musical texture through instrumental doubling, the listener is reminded that other patterns exist beneath the surface of the music. Essentially, Reich is inviting the listener to exercise schema-based segregation processes based on voluntary attention. The fact that solo patterns are lost in perception shortly after their volume is decreased, suggests the strong presence of primitive processes in partitioning the interlocking patterns into registral streams (which obstructs, or prevents the bridging of melodies from one stream to another). By measuring the extent of this effect, we are inquiring into the strength of the primitive process, which forces certain patterns to be excluded from awareness because of the strength of registral partitioning.

One of the most significant features of *Violin Phase* is Reich's conscious employment of resulting patterns:

> The live violinist's process of "pointing out" the resulting patterns guides the listener's perceptions and opens up the listener's ears to melodic combinations he or she may not have heard: the effect is almost that of bringing a transitory aural illusion into the realm of reality. (Reich, 1974)

At $T_{0,8(8)}$, the live violinist selects patterns from the composite patterns formed by violins 1 and 3 (tape track 2). Again, during the region $T_{0,8(4)}$, patterns are selected from the composite patterns formed by violins 1, 3 and 4 (tape tracks 1 and 2).

> If the violinist so desires, he or she may pick out alternating resulting patterns which actually exist in the overall combination. These alternate resulting patterns, in their most musical order, may be written down in the blank bars supplied at the bottom of each system. A violinist should only attempt to use alternate resulting patterns if he or she spends a good

deal of time preparing them so that he or she feels they are more musically satisfactory than those written in the score. (directions for performance)

The fact that the "alternating resulting patterns" fade in and out (indicated by crescendo and decrescendo markings) adds to the impression that the patterns are emerging out of nowhere. This effect is created because the solo patterns are not held in awareness prior to their illumination. I argue that the presence of doubled patterns temporarily freeze the ambiguous play of the musical system, and that in these regions, the interlocking patterns take on the role of accompaniment. When the doubling subsides, listeners are able to maintain or continue to impose the pattern on the interlocking structure for a short time after they fade out. After some time however, the free play of the system is restored. This phenomenon can be compared with the "mysterious looming up" of patterns in Bugandan xylophone music where the singer verbalises inherent patterns. The looming up effect is created by bringing otherwise dormant patterns into awareness.

Resulting patterns can be thought of as cellular patterns, which are created out of existing units of the composite patterns. As stated by Reich in relation to *Phase Patterns*, "naturally a resulting pattern must actually exist within the complete resulting pattern of organs 1 and 2, however it need not be limited to one bar length..." (directions for performance). In the following discussion, the recommended solo patterns in *Violin Phase* and *Phase Patterns* (here referred to as cellular patterns) are closely examined to assess their contribution to the temporality of these works.

While the prolongation region $T_{0,8(8)}$ in *Violin Phase* remains fixed, the live violinist introduces the first set of doubled resulting patterns. The composite pattern created by two violins at $T_{0,8(8)}$ is provided in Figure 4-19, so that the source of each cellular pattern in this region can be observed.

Figure 4-19 Composite pattern at $T_{0,8(8)}$

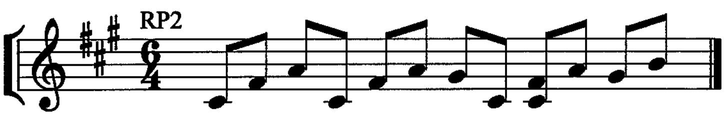
With the exception of one attack-point, the selected (recommended) pattern shown in Figure 4-20 highlights the set of E double stops created by the set [0257] in this region. In this sense, the solo pattern shares a complement relation with one of the principal bc sets.

Figure 4-20 Cellular pattern #1 in $T_{0,8(8)}$, *Violin Phase*

Despite this, its presence is significantly felt as a result of increased dynamics. The "double-stop" feature of this set is perhaps felt much more strongly in its solo presentation, because primitive segregation tends to isolate the high 'E's', and the 'A' and 'B' are potentially stripped from the set due to being captured by notes belonging to lower streams.

The second recommended resulting pattern (Figure 4-21), which is also supported by the region $T_{0,8(8)}$, does not correspond directly with any of the principal bc sets. Rather, it is made up of the low C# set, and several intermediate notes. Because this solo patterns is made up of notes from both the higher and lower streams (loosely partitioned by primitive segregation), the effect of "bringing a transitory aural illusion into the realm of reality" is more striking than in the previous example, as if it was buried deeper in the musical texture. Similarly, its subsumption back into the texture prohibits the listener from being able to hold the pattern in awareness, despite the fact that the listener has had time to become familiar with it. Interestingly, the volume is the only tool used by Reich to accentuate and distinguish the solo patterns. The articulation, and all the other factors which potentially favour coherence, are not exploited in many of the recommended patterns. Rather, they mimic the orderliness of interlocking patterns.

Figure 4-21 Cellular pattern #2 in $T_{0,8(8)}$, *Violin Phase*



The third and final solo pattern in this section is the longest, and makes full use of the pitch range formed by the composite patterns in the $T_{0,8(8)}$ transposition (Figure 4-22). Every note in the composite pattern is used in this solo, and the pattern is more rhythmically diverse than the previous two examples. This suggests that the effect of "looming up" out of the texture will be most striking, and that after fading out, the pattern will be extremely difficult to hold in awareness, due to the forces of primitive segregation.

Figure 4-22 Cellular pattern #3 in $T_{0,8(8)}$, *Violin Phase*

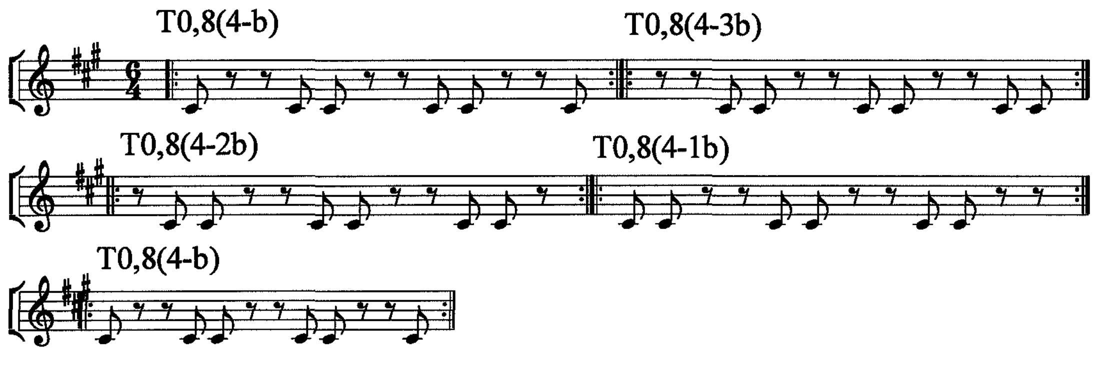
The first resulting pattern at $T_{0,8(4)}$ imitates the configuration formed by the high set [0257] (see Figure 4-23). As can be seen however, it emphasises the tied note of the composite pattern on beat 1 (using a crotchet), and beat 5 (using tied notes) of the cycle.

At the end of this first cellular pattern, the solo violin engages in a phasing process of its own. In figure 4-23 above, I have labelled these sections as $T_{0,8(4-a)}$; $T_{0,8(4-3a)}$; $T_{0,8(4-2a)}$; $T_{0,8(4-1a)}$ to indicate the three accelerations that take place. The "a" in each label denotes the first appearance of solo phasing in the composition.

Figure 4-23 Cellular pattern #1 in $T_{0,8(4)}$, *Violin Phase*

The second cellular pattern in this region, shown in Figure 4-24, very simply articulates the set of low C#'s derived from the basic low set [05], whose cardinality is 6 in the $T_{0,8(4)}$ region. This cellular pattern is rotated through 3 beats of the cycle, hence the labelling: $T_{0,8(4-b)}$; $T_{0,8(4-3b)}$; $T_{0,8(4-2b)}$; $T0_{,8(4-1b)}$; and the return to unison, $T_{0,8(4-b)}$.

Figure 4-24 Cellular pattern #2 in $T_{0,8(4)}$, *Violin Phase*



The solo pattern shown in Figure 4-25, again a phasing pattern, utilises notes from the middle register of the composite pattern in the region $T_{0,8(4)}$, articulating every beat of the cycle. For the first time, an alternative articulation is specified. The staccato markings facilitate the emergence of this pattern, which may otherwise by dominated by the registral extremes of the composite pattern, that is, the high E, and the set of low C# attacks. In addition, this articulation might draw attention away from the previous cellular pattern which exploited the low C#'s. The phasing regions of this pattern are labelled $T_{0,8(4\text{-}c)}$; $T_{0,8(4\text{-}3c)}$; $T_{0,8(4\text{-}2c)}$; $T0,_{8(4\text{-}1c)}$, and $T_{0,8(4\text{-}c)}$, the return to unison.

Figure 4-25 Cellular pattern #3 in $T_{0,8(4)}$, *Violin Phase*

The final pattern played by the live violinist, shown in Figure 4-26, continues for the remainder of the composition. Although it is not phased using accelerations (like the previous patterns in this region), variety is achieved by the length of the pattern which is two and a half times that of the 12-beat cycle (so it is still revolving against the $T_{0,8(4)}$ pattern).

Figure 4-26 Cellular pattern #4 in $T_{0,8(4)}$, *Violin Phase*

Like the final cellular pattern over $T_{0,8(8)}$, the rhythmic characteristics of the pattern are varied, and, with the exception of the high E, it exploits the full range of the notes in the composite pattern.

I propose that the solo patterns in *Violin Phase* significantly distort the clarity of beat-class sets of the phasing patterns, which take on the role of accompaniment in their presence. Similarly, the following inspection of doubled patterns in *Phase Patterns* weakens the argument that the listener will perceive the linear progression formed by the gradual increase in attack-points throughout the work.

The recommended doubled patterns in region $T_{0,7}$ of *Phase Patterns*, shown in Figure 4-27, are notated in full, to demonstrate that the bc sets identified by Cohn must take on a secondary role in the presence of new patterns. An assessment of temporality in these works cannot ignore the effect that these doubled patterns have on the salience of beat class sets derived from only 2 out of 4 of the instruments participating in the music. The example below shows that organs three and four, which are played louder than organs one and two, have the potential to form their own resulting patterns. At this point in the composition, new resulting patterns, formed from the union of organs three and four will dominate the surface of the music. This suggests that an argument for linearity based on interlocking structures for organs one and two alone is incomplete.

The example provided in Figure 4-27 is indicative of the complexity in these works which is generated by the simultaneous activity of interlocking structures. I argue that a judgement of temporality in this music is better understood by acknowledging the full extent of perceptual ambiguity in these works, which results from the segregation of interlocking structures, in combination with the segregation of doubled patterns. A thorough understanding of resulting percepts can only be gained by acknowledging the susceptibility of these structures in relation to auditory stream segregation.

Figure 4-27 Recommended patterns for organs 3 and 4 (over $T_{0,7}$) in *Phase Patterns*

Audibility of the principal pattern

Although the principal patterns are fixed throughout the entire composition, they move from the foreground to the background of the texture depending on the activity of the mobile pattern. There are several factors, however, that contribute to the audibility of the original pattern. For example, in phase one ($T_{0,11}$), the frequent occurrence of major seconds distorts the contour of the original pattern only marginally. It is not until phase two that the two voice division is recognised clearly (see Figure 4-28). Epstein (1986) acknowledges that there may be a notable variance in the listening experience from one person to another, and from one hearing to another. He states that with selective listening, it is possible to "retain the old pattern a bit longer, or jump to the new one a bit sooner" (p. 500).

Figure 4-28 Two-voice divisions of the texture in *Piano Phase*

Metric and rhythmic ambiguity

An additional area of interest in the music, and a more general one, concerns the nature of meter. As recognised by Epstein (1986), "in much of the music of pattern repetition, meter is largely a quantitative factor; one hears that a figure repeats after so many beats, but there is no functional down beat - or several accents may compete for primacy" (p. 500). In relation to *Piano Phase*, Epstein states that "this non-hierarchic meter helps to propel the music forward by eliminating the heavy articulation of an unambiguous metric accent" (p. 501). He also suggests that "either momentary inattention or the emergence of a new subpattern will result in a metric reorientation" (p. 501). Dennis (1974) also comments on the rhythmic nature of *Piano Phase*. His rhythmic and structural observations are summarised below:

1. In general, accents tend to polarise towards the highest and lowest notes (i.e. away from the B) and both areas contain notes from the rhythmic groups of four and six. Thus considerable rhythmic variety is assured even when the module appears on its own.
2. In various phases two-note chords emerge which accent the material in a variety of ways. For example, in phase 3 a strong triple rhythm is broken at the end of the figure; in phase 6, the melodic aspect is submerged by the unison on E, B, and D and the strong off beat C# and F# chord which is probably heard as the downbeat.

3. The momentary aural confusion as one pianist speeds up is greatly enhanced where there is an abrupt shift of accent (i.e. the emergence of a new 'synthetic' downbeat).

According to Jones' rhythmic theory of attention, "regular patterns should afford better prediction, and therefore, better integration" (Bregman, 1990, p. 411). This implies that prolongation regions containing more rhythmically complex structures will be less likely to divide clearly into registral streams. In order to test these assumptions, Chapter 5 investigates listeners' perception of pulse in the prolongation regions of *Piano Phase*.

Accelerations

The gradual separation of patterns during the acceleration regions of Reich's phase shifting music generate rhythmically chaotic fields. The complexity of these regions, causing sudden perceptual shifts to occur, makes specific predictions about future events unlikely. Jones' rhythmic theory of attention (discussed in Chapter 2) has different implications in these regions. As mentioned, her theory suggests that the process that is responsible for the formation of streams is one that makes predictions about the properties of the next sound. As stated above, this implies that "regular patterns should afford better prediction, and therefore, better integration" (Bregman, 1990, p. 411). In the highly irregular acceleration regions of Reich's phase shifting music however, the registral grouping of events is prominent, suggesting that primitive segregation processes are responsible for their partitioning. This implies that the participation of schema-based processes during these regions is likely to be minimised, because there is no regularity in the system from which listeners can develop expectations. Therefore, Jones' theory seems unable to accurately describe grouping processes in this music, and consequently, in many types of contemporary music where random sequences of notes are central to the musical experience. Rather, Jones' theory is more appropriate for describing grouping processes in 'linear' music, where expectations are set up, and future events more easily anticipated.

Summary

In accord with the research questions proposed, the beat-class analysis conducted in this chapter looked for further evidence of linear structures in Reich's phase shifting music. The analysis revealed that the principal sets of *Piano Phase* and several primary beat-class sets in *Violin Phase* (sets [05] and [024579]) do not demonstrate a steady progression toward a foreseeable goal. In contrast, there was little variation in the structural design of attack-point frequencies. That is, the principal sets often contained consecutive regions with identical attack-point frequencies, revealing comparatively non-goal directed structures.

I do *not* suggest that the progressive design of attack-points in *Phase Patterns* and *Violin Phase* (set [0257]) do not have any impact on the temporal experience of these works. As suggested by Kramer,

> There is a continuum between the directly audible and the wholly inaudible. Thus it represents an oversimplification even to try to know whether relationships and elements can or cannot be heard. (Kramer, 1988, p. 329)

Rather, the approach adopted in this study emphasises the different types of temporal forces active in the music, to contribute to an understanding of why Reich's phase shifting music is often described as nonteleological. The central question addressed is: What characteristics of the music have the capacity to divert the listeners' attention away from broader linear structures, and "forc[e] the mind inward on small structural details" (Schwarz, 1981, p. 378)? In order to explore these "small structural details", the following chapters investigate the perceptual processes which are responsible for their formation. The analysis of 'cellular patterns' brought about by instrumental doubling, suggested that their effect represents a reflection of the structure of our perceptual systems, that is, the limitations of our perceptual ordering faculties. For example, a cellular pattern crossing auditory streams is more difficult to hear when it is subsumed back into the texture, that is, when there are no cues to perceptual grouping such as loudness or articulation. I argue that the complexity of vertical structures in the music, created by the simultaneous activity of interlocking structures, has the capacity to dissolve, or minimise the impact of larger structural forces.

As suggested by John Cage, the purpose of nonteleological music "is to be perceived, not to communicate" (Kramer, 1988, p. 384). That is, the role of perception takes on a very different significance in this music. Therefore, the experiments reported in the following chapters respond to the heightened role of the listener in nonteleological music:

> If a nonteleological piece is to be appreciated and enjoyed, the listener must become a creative participant in making the music. He or she must chunk it, according to individual criteria (since the music usually lacks unequivocal cues). He or she must create its hierarchies. He or she must provide contrast, by focusing attention on different aspects... In this way, he or she becomes part of the music, and thus the distinction between the self and the other, the listener and the music, is minimised. (Kramer, 1988, p. 384)

For these reasons, I argue that music which minimises the distinction between "the listener and the music" is benefited by analysis which gives equal weight the structural characteristics of the music, and the listener's perceptual processes which contribute significantly to the experience of it. The first level of this perceptual inquiry focuses on the influence of resulting patterns on listeners perception of pulse in Reich's *Piano Phase*.

Chapter 5

Pulse Perception in *Piano Phase*

Introduction

In Chapter 2, I advocated a multifaceted approach to researching musical temporality (Barry, 1990), which subsequently influenced the range of analytic approaches adopted in this study (formal, analytic, empirical, and experiential). The reason for such an approach is to examine the relationship between levels of linearity and nonlinearity in Reich's early works. In Chapter 4, I provided an objective analysis of Reich's phase-shifting music using formal analytic techniques. By contrast this chapter reports two experiments (1A and 1B) which are concerned with 'experiential time'. The aim is to investigate the musical temporal experience by considering "how inherent and individual factors are inter-related...and how musical time passes" (Barry, 1990, p. 86).

The results of the experiments presented in this chapter are not meant to be considered in isolation, but rather in conjunction with the musical analysis, the theoretical evaluation of the role of stream segregation (presented in Chapter 4), and the two experiments reported in Chapter 6. The success of this integrative approach is considered in Chapter 7, which examines the temporal characteristics of Reich's compositional output after 1971.

The Pilot Study

Experiments 1A and 1B were preceded by a pilot study in order to test several aspects of the experimental design and procedure.

Aim

Experiments 1A and 1B, reported in this chapter, test the salience of various pulse sensations in Reich's *Piano Phase*. Relative to other studies of pulse perception, the patterns in *Piano Phase* are complex musical stimuli. As a control, the pilot tested the salience of pulse sensations in the simplest rhythmic patterns: a series of isochronous sequences. Previous research (Handel & Lawson, 1983; Parncutt, 1994) has shown that the slower the tempo of isochronous sequences, the more regular the pulse sensation. That is, pulse sensations have a tendency to gravitate toward moderate tempi (400-900 ms) (Parncutt, 1994, p. 418). At moderate to fast presentation rates, the perceptual grouping of isochronous sounds has been described as subjective rhythmisation (Parncutt, 1994). Based on the results of Parncutt's study (1994), groups of four should occur more often than groups of three in isochronous sequences, independent of presentation rate.

In addition to examining perceptual grouping, the pilot study measured the distance between subjects' pulse responses and the actual beat. This information was used to test the effect of tempo on the 'accuracy' of subjects' responses, and to ensure that there would be no confusion as to which sound events matched subject's pulse responses.

Method

Stimuli

Stimulus patterns consisted of an isochronous sequence that was presented at five different pattern rates. Pattern rates (tempi) were defined by the distance (in milliseconds) between note onsets. As shown in Figure 5-1, the five different pattern rates were: 139 ms, 150 ms, 200 ms, 250 ms, and 300 ms. The pattern rates and the piano sound (from a Kurtzweil 2000) chosen for the experiment were identical to those used in Experiment 1A. Sequences were presented at the same pitch and volume for all subjects.

Figure 5-1 Stimulus patterns used in pilot study

For each sequence, the duration of tones was 50 ms less than the distance between note onsets, that is, durations were 89 ms, 100 ms, 150 ms, 200 ms, and 250 ms respectively. The sequences were all 144 tones in length, so that deviations could be calculated over the period of time subjects would be responding (tapping) in the main experiment (Experiment 1A). The sequences were created on a Macintosh computer using Max 3.5. Descriptions of the software are provided in the methodology section of Experiment 1A below.

Subjects

Fourteen subjects participated in the pilot study. The subject sample consisted of nine musicians and five non-musicians. Additional information regarding subjects is provided in detail in the 'Subjects' and 'Questionnaire' sections of Experiment 1A (the questionnaire is included in Appendix D).

Procedure

The researcher explained the opening screen of the experiment to subjects, and they were asked to follow the instructions on the screen as they appeared (see Appendix E). Subjects were asked to tap the space-bar of the computer keyboard in time with the set of isochronous sequences.

After each trial, subjects were asked to estimate the accuracy of their taps using a four-point rating scale: "1" indicating "very poor" accuracy (a wide deviation from the events of the sequence), and "4" indicating "good" (very little deviation).

The accuracy of the space-bar as a device for registering subject responses was validated in a pilot study which is reported in Appendix C. The results of this pilot demonstrated that the accuracy of recording subject's taps was not hindered by the position of taps on the space bar (where on the key subjects tapped). In addition to the size and position of the space-bar on the computer keyboard, the findings reinforced the suitability of the spacebar as a device for registering subject's responses in the pilot study and main experiments reported in this chapter.

Results and Discussion

Table 5-1 shows the number of times subjects chose different periods for each of the five presentation rates.

Table 5-1 Frequency with which different periods were selected by subjects

Period	139 ms	150 ms	200 ms	250 ms	300 ms	Total
1	-	-	-	4	3	7
2	6	5	7	5	7	30
3	-	-	-	-	-	-
4	5	7	6	5	4	27
6	1	-	-	-	-	1
8	2	2	1	-	-	5

The total number of times subjects chose different perceptual groupings is shown in the right hand column. Overall, the table shows that periods of 2 were chosen most frequently by subjects overall. In accord with Handel and Lawson (1983) and Parncutt (1994), more regular pulse sensations were evoked in slower sequences. For example, periods of 1 were selected on seven occasions at the two slowest presentation rates. No subjects chose periods of 1 for the faster sequences. Also in accord with Handel and Lawson (1983) and Parncutt (1994), periods of 8 were only evoked in the three fastest presentation rates.

The results satisfy the prediction (Parncutt, 1994) that groupings of 4 will occur more frequently than groupings of 3 in isochronous sequences. While no subjects chose groupings of 3, one subjects chose a grouping of 6 for the fastest tempo. While this is considered an irregular result, it does concur with Parncutt's (1994) evidence that pulses tend to gravitate toward moderate tempo, which he defines as somewhere between 400-900 ms.[9] The results of the pilot study tend to support this aspect of Parncutt's model.

Table 5-2 Distance between subject taps and sound events (in milliseconds)

Subject	139 ms		150 ms		200 ms		250 ms		300 ms	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
1	30.17	23.28	45.36	15.72	26.54	13.28	32.32	14.03	18.39	15.43
2	28.70	9.47	41.47	14.38	23.24	13.60	22.93	12.32	25.59	14.31
3	39.76	14.29	44.37	24.55	61.56	13.15	34.12	18.77	23.36	18.39
4	67.56	16.01	66.71	28.50	30.29	17.18	32.84	13.40	39.85	12.28
5	30.73	13.55	4.63	20.95	12.42	13.51	19.78	17.08	15.85	15.85
6	37.86	8.94	41.09	14.52	24.78	12.14	25.66	13.66	40.07	15.75
7	43.06	22.18	42.65	28.29	38.82	23.80	13.38	13.97	33.86	27.20
8	40.18	11.67	73.53	19.87	30.15	13.68	22.65	17.63	28.53	22.34
9	66.74	41.28	45.45	33.30	17.71	23.50	20.80	26.92	28.29	26.28
10	44.39	11.92	41.72	15.38	83.49	45.76	72.24	27.11	43.43	17.82
11	44.42	23.00	32.35	11.03	25	11.25	19.49	12.98	39.63	19.37
12	45.16	31.27	40.43	12.75	50.18	19.60	33.13	28.62	47.58	16.26
13	55.15	21.88	54.06	22.48	49.69	14.11	43.28	13.30	18.58	18.58
14	45.18	22.19	60	17.19	33.03	22.71	20.44	20.83	34.21	16.76
Total	**619.06**		**633.82**		**506.9**		**413.06**		**437.22**	
Min	28.70		4.63		12.42		13.38		15.85	
Max	67.56		73.53		83.49		72.24		47.58	

Table 5-2 shows the mean distances between subject taps and the sound events for all subjects and for all presentation rates. The maximum average deviation was 83.89 ms (at the presentation rate 200 ms), and the minimum average deviation was 4.63 ms (at the presentation rate 150 ms).[10] Subject taps were assumed to match sound events when taps fell within half the distance between consecutive note onsets.

[9] For example, where p=6 at 139 ms, subjects tapped every 834 ms, falling within the region of moderate tempo as defined by Parncutt (1994).

[10] It was not deemed appropriate to test whether the distance between subject taps and sound events decreased across the five presentation rates because the number of taps recorded for each trial varied for different subjects. For example, subjects who tapped every two beats had up to 72 data points, while subjects who tapped periods of 4 had up to 38 data points (depending on when they began tapping).

In agreement with previous studies (Parncutt, 1994; Handel & Lawson, 1983), the results for the perceptual grouping of isochronous tones revealed the following:

1. subjects chose groupings of two and four most frequently, and none chose groupings of three;
2. slower sequences tended to evoke more regular pulse trains;
3. faster sequences tended to evoke less regular pulse trains;
4. pulse responses tended to gravitate toward moderate tempo (400-900 ms) as defined by Parncutt (1994)[11]; and
5. all pulse responses fell within Parncutt's existence region of pulse sensation (200-1800 ms)[12]

The results of the pilot study and previous research evidence, as cited above, confirmed the validity of employing the same method of recording data in the main Experiments (1A and 1B), which test listener's perception of pulse in Reich's *Piano Phase*.

Experiment 1A: Pulse Salience in Reich's *Piano Phase*

In Chapter 4, I discussed several aspects of rhythm in Reich's phase-shifting works. I suggested that contemporary music based on the repetition of small motifs often resists functional downbeats. Several researchers have observed that much of Reich's music is characterised by a steady, driving pulse (for example, Schwarz, 1981). Although a listener may identify the cyclic repetition of a motif in Reich's phase-shifting music, metric instability can occur when several accents compete for primacy (Epstein, 1986). When new sub-patterns emerge from the musical texture, the listener must reinterpret the metric structure of the music. It is expected therefore, that although the actual music is unchanging during prolongation regions, current metric templates are renewed when they no longer accommodate new resulting

[11] This was established by multiplying the tempi (distance between note onsets) with the most commonly selected period. For the slowest presentation rate (300 ms), for example, the most commonly selected period was two. That is, the distance between subject taps was 600 ms, falling within the region of moderate tempo (400-900 ms) as defined by Parncutt (1994).

[12] Once again, this was established by calculating the actual distance between subject taps in milliseconds based on tempi and selected period.

patterns. The extent of the metric renewal process depends on how frequently new patterns arise from the musical texture, and how actively the listener seeks them out.

The experiments reported in this chapter were designed to test the assumption that different patterns within a passage of music will induce different metric groupings. For example, a pattern derived from the high stream might be felt in groups of 4 beats, while a pattern derived from the low stream might be felt more strongly in groups of 6 beats. The sudden perceptual shifts which occur in Reich's early works can be viewed, in part, as the process of metric reorientation of the type examined in the experiments which follow. The attention of the listener plays an important role in the frequency of these shifts, because metric reorientation might result from momentary inattention or the appearance of a new sub-pattern (Epstein, 1986). In Chapter 4, I discussed the unstable nature of Reich's phase-shifting music in relation to van Noorden's (1975) fission and segregation boundaries. I argued that the music has been constructed so that a range of possible patterns are close to the surface of the texture, and may emerge with or without the listener's volition.

Theoretical Background

Although there are several existing models of meter and pulse perception (discussed below), none have direct application to the present study. Most models of meter perception (Lee, 1991; Longuet-Higgins, 1976; Longuet-Higgins & Lee, 1982, 1984; Longuet-Higgins & Steedman, 1971; Povel & Essens, 1985; Rosenthal, 1992) are based on the contribution of duration to phenomenal, or subjective, accent. For example, they are concerned with the impact of certain note values on subsequent and proceeding tones. This type of durational variation is uncommon in Reich's early works. Although *Phase Patterns* is made up of a series of notes and rests, all sounded notes are of equal value. In *Piano Phase,* the principal pattern is attacked (in semiquavers) on every beat of the twelve beat cycle. The *perceived* rhythms in Reich's phase-shifting music, however, do not simply constitute a sequence of twelve undifferentiated beats. Rather, the perceived rhythms are a product of stream segregation, which segregates the texture to allow a range of potential sub-patterns (see Chapter 4). *Violin Phase* is the only phase-shifting composition to contain durational variation in its principal pattern, where a tied note occurs on beat 5 of the twelve beat cycle (refer to Chapter 4, Figure 4-5).

All theories of meter, with the possible exception of Longuet-Higgins and Lee (1984) state that notes with longer durations are more salient than shorter notes, and therefore, it is more probable that they will initiate major metrical units (Lee 1985, 63). Some theories (Lerdahl & Jackendoff, 1983; Longuet-Higgins & Lee, 1984; Povel & Essens, 1985) state that the listener will try to ensure that beats coincide with note onsets in particular ways, regardless of the lengths or durations of the notes in question. All theories stress that repetition (the occurrence of repeated sequences) is an important metrical cue. Several theorists (Longuet-Higgins & Steedman, 1971; Steedman, 1977; Longuet-Higgins & Lee, 1982; Lee, 1985) argue that processing considerations are important because the history of the listener's metrical judgement, during the course of listening to a sequence, influences their final interpretation.

Another influence on the methodology chosen for the experiments was Richard Parncutt's (1994) model of pulse salience and metrical accent, which recognises the "inherent ambiguity of the underlying pulse (tactus) and meter of rhythm" (p. 423). Parncutt's model does not generate a single solution, but considers a range of potential pulse and meter sensations, and estimates their relative salience. For these reasons, it resembles the models proposed by Povel and Essens (1985), Lee (1991), and Rosenthal (1992).

Several aspects of Parncutt's model are applicable to the two experiments to be reported in this chapter. For example, in Parncutt's research, the perception of pulse trains in musical patterns is conceptualised as a process by which sound onsets are matched against an isochronous template. A given template is defined by two pieces of information, its 'period' (P) and its 'phase' (Q). The period is the interval of time between successive events, and the phase is the "actual time at which any of the events occur, relative to some reference time" (Parncutt, 1987, p. 132). The 'salience' of a pulse sensation is defined by Parncutt as "the perceptual (and hence musical) significance, strength, or prominence of a pulse sensation" (1994, p. 413). Although several different pulse sensations may be evoked by musical patterns, one will usually be heard as dominant, acting as a referent time level (Jones & Boltz, 1989). Usually the referent time level is defined by a moderate tempo, that is, an intermediate level (Parncutt, 1994, p. 413). The pulse sensation with the highest salience is referred to as the 'tactus' (Lerdahl & Jackendoff, 1983; Parncutt, 1994).

Parncutt (1994) states that the closer the tempo of a pulse is to moderate tempo, the greater the salience of the corresponding pulse sensation. The tendency for pulse sensations to gravitate toward a moderate tempo is explained by Parncutt (1994) according to an "existence region of pulse sensation". The extent of the existence region is determined by having listeners tap out the tactus (main or underlying beat) of a musical excerpt or rhythm. Parncutt (1994) makes the following statements regarding the existence region of pulse sensation.

1. The most salient pulse sensations have a moderate tempo of about 100 isochronous events per minute, or a period of about 600 ms;
2. The region of greatest pulse salience (defined as the dominance region) lies between about 2/3 and 3/2 times moderate tempo. That is, 67-150 events per minute, or 400-900 ms; and
3. Pulse sensations cease to exist outside the boundaries of about 1/3 or three times moderate tempo. That is, faster than 200 ms and slower than 1800 ms (33 - 300 events per minute) (1994, p. 437).

Aim

Based on the above information, it was decided to devise an experiment (1A) which would address the ambiguity of pulse perception in Reich's music. The purpose was to test six assumptions related to the perception of pulse in the prolongation regions of Reich's *Piano Phase*:

1. subjects will exhibit a diverse range of pulse-train responses in each region;
2. pulse-trains matching the greatest number of note onsets will be more salient;
3. the majority of pulse sensations will fall within dominance region of pulse salience (400-900 ms), and all sensations will fall within the existence region of pulse sensation (above 200 ms; and below 1800 ms);

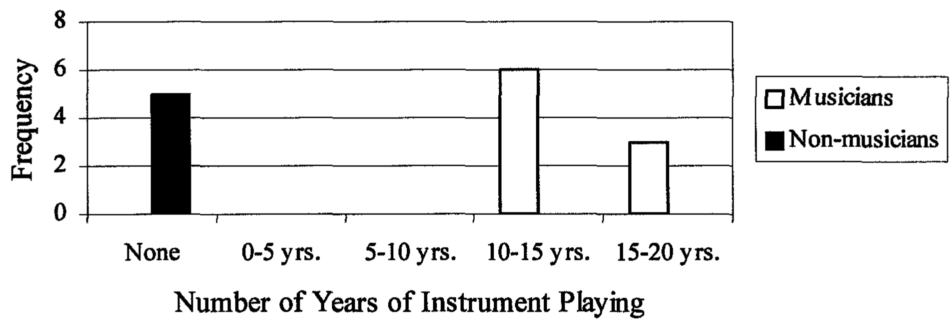
4. slower sequences will result in more rapid pulse trains, while faster sequences will result in broader referent time levels;
5. any repetition inherent in a pattern will act as a metrical cue; and
6. *doubled attacks* will increase the salience of pulse sensations.

Methodology

Subjects

Fourteen subjects, comprising nine females and five males, participated in the experiment. Discussions with three music psychologists suggested that the participants should be separated into musical and non-musical groups on the basis of how many years they had studied a musical instrument. The subject sample consisted of nine musicians and five non-musicians whose musical experience ranged from 0-17 years (mean of musicians = 8.2 years). Figure 5-2 shows the distribution of people who had learnt at least one instrument. Five participants in the group had never learnt a musical instrument. The remaining subjects had at least ten years of playing experience, with a majority of musicians having studied a musical instrument for between ten and fifteen years. The subject sample was intended to clearly distinguish musical and non-musical groups. Consequently, no subjects had between zero and ten years of playing experience.

Figure 5-2 Number of Years of Instrument Playing



The type of musical instruments played by subjects was diverse. With one exception, all subjects in the musicians group played more than one musical instrument. Non-musicians had no prior practical or theoretical training in music.

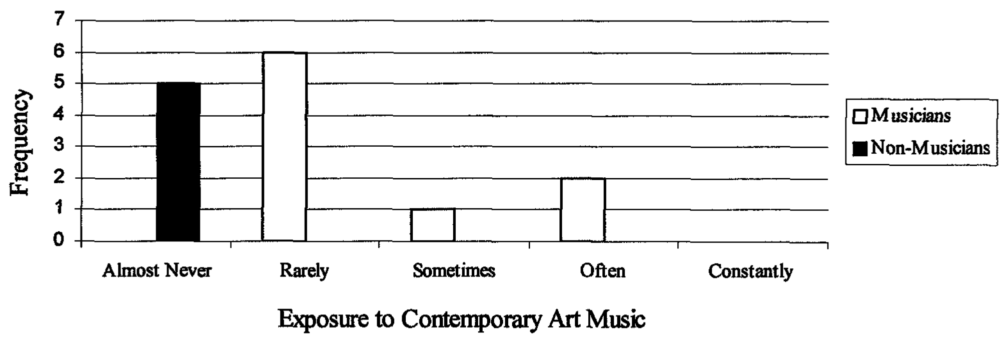
The youngest participant was 21 years of age, and the oldest was 54. The mean age of participants was 26.9 years. Of the fourteen subjects nine were between 20 and 30 years of age, with seven of these subjects being enrolled full time in undergraduate courses in Music or Music Education at the University of New South Wales.

Questionnaire

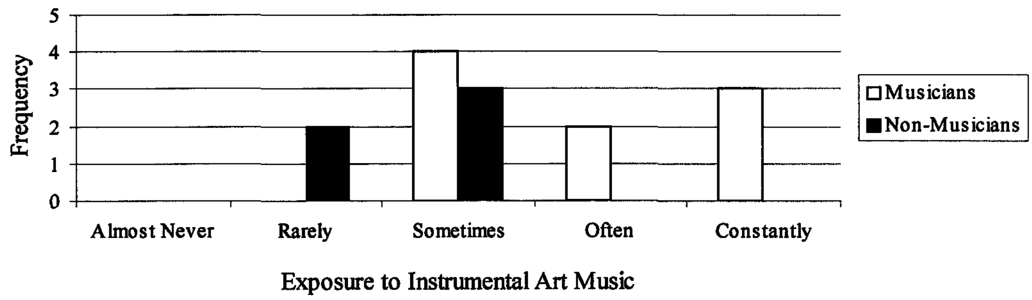
A questionnaire (see Appendix D) was completed by all participants prior to the experiment. Section A of the questionnaire collected details of subjects' musical background and training. Subjects were asked to indicate, on a five-point rating scale, the amount of time they spent listening to a range of musical styles (1 Almost never; 2 Rarely; 3 Sometimes; 4 Often; 5 Constantly). The results for contemporary art music, Western instrumental art music, and non-Western music are shown in Figure 5-3. These styles are considered because of their relationship to Reich's music, which is contemporary instrumental music resembling certain non-linear characteristics of non-Western music such as Javanese gamelan and African drumming and xylophone music.

Figure 5-3 Level of exposure to various types of music

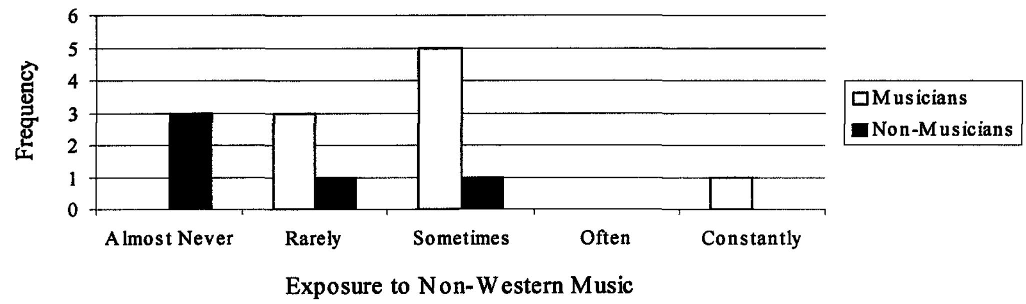
a.



b.



c.



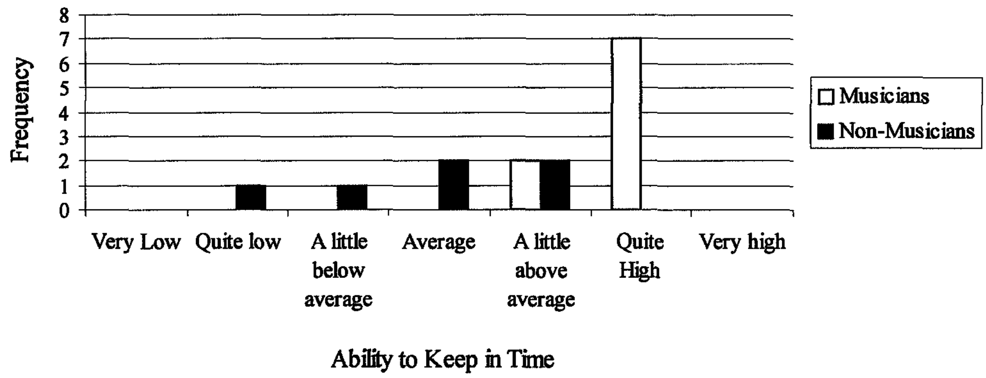
The results in Figure 5-3 indicate that both musicians and non-musicians reported moderate levels of exposure to instrumental art music, with much less exposure to contemporary art music and non-Western music Generally, musicians had a greater level of exposure to instrumental music than non-musicians (Figure 5-3b). On average, subjects indicated a low level of exposure to contemporary art music (Figure 5-3a). Subjects who indicated that they almost never listened to contemporary music were all non-musicians. Only three musicians of the nine reported a moderate to high level of exposure to contemporary music. The majority of musicians listened to non-Western music sometimes, while three of the five non-musicians indicated that they almost never listened to non-Western music.

Section B of the questionnaire was designed to collect information regarding subjects' attitudes toward music. Subjects' interest in music was measured by asking participants how much they enjoyed listening to various styles of music on a seven-point rating scale (1 Not at all; 2 Very little; 3 A small amount; 4 A fair amount; 5 Quite a bit; 6 A lot; 7 A great deal).

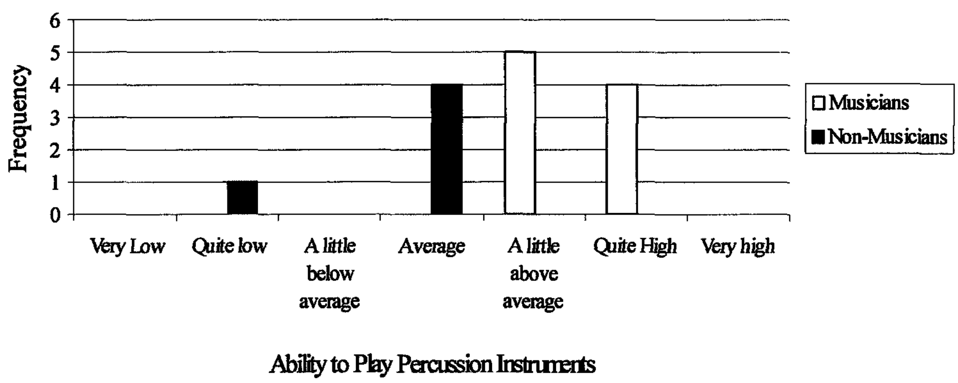
The set of questions in Section C of the questionnaire asked subjects to rate their aptitude for performing a range of musical tasks in terms of their ability to play an instrument, read music, compose, improvise, keep in time, and play percussion instruments. Questions were answered on a seven-point scale from "very low" to "very high". Due to the nature of the tapping task in the experiment, several of these questions targeted subjects rhythmic ability. Figure 5-4a shows the frequency of responses for the question in which subjects were asked to rate their ability to keep in time when singing or playing. Figure 5-4b shows the frequency of responses for the question which asked subjects to rate their ability to play percussion instruments.

Figure 5-4 Responses for keeping in time when singing or playing, and ability to play percussion instruments

a.



b.



The results shown in Figure 5-4 indicate that participants reported an average to high level of ability to keep in time when singing or playing, and to play percussion instruments. Only one non-musician reported being below average at both skills. Generally, these self reports suggested that neither musicians and non-musicians would have difficulty performing the tapping task in the experiment.

The mean response (on the seven-point scale) for all thirteen questions related to musical ability in Section C of the questionnaire were calculated for each subject. For musicians, the mean scores on the seven-point scale ranged from 5.15 to 6.08, while for non-musicians the means were lower, ranging between 1.46 and 3.85. These results suggest clear differences between the two groups.

Subjects were asked to fill out an additional section of the questionnaire (Section D) at the completion of the experiment. The questions in this section were designed to find out if any problems were encountered during the experiment. For example, subjects were asked if they had any difficulty following the instructions, and to rate the difficulty of the tapping task. In addition, subjects were asked if they were familiar with the excerpts presented in the experiment. No subjects reported having difficulty following the instructions. Of the fourteen subjects, twelve reported that the tapping task was moderately easy, and none found the task difficult. Of the musicians, two had heard the music once or twice, two reported knowing the music reasonably well, and three were not sure if they had heard the music before. No subjects in the non-musicians group reported having heard the musical excerpts presented in the experiment.

In order to confirm that the questionnaire items were suitable for assessing subjects musical ability (or categorising subjects into musical and non-musical groups), three experts from the School of Music and Music Education at the University of New South Wales were consulted. These people included the Head of the School of Music Education, a senior lecturer, and one doctoral candidate. All agreed that the questions provided a suitable basis for categorising subjects according to musical and non-musical groupings.

Stimuli

Figure 5-5 shows the stimuli used in the experiment. The seven sequences (the principal pattern and the first six prolongation regions of *Piano Phase*) were repeated using five different tempi (139 ms, 150 ms, 200 ms, 250 ms, 300 ms) making a total of 35 trials. As in the pilot study, pattern rate was defined by the distance between note onsets. The duration of tones was set at 50 ms less than the distance between tones. That is, durations were 89 ms, 100 ms, 150 ms, 200 ms and 250 ms depending on the tempo of the sequence. The patterns were used to examine periodic grouping, and the ambiguity of the downbeat in each region. The labels given to each pattern are consistent with the musical analysis presented in the previous chapter. That is, they are denoted by $T_{0,0}$ (principal pattern), $T_{0,11}$, $T_{0,10}$, $T_{0,9}$, $T_{0,8}$, $T_{0,7}$ and $T_{0,6}$. Only the first six permutations of the original pattern were used, because the last five regions contain the same pattern structure as $T_{0,11}$ through to $T_{0,7}$ (although they begin on different beats of the cycle). The tempo 139 ms was chosen because it is the recommended tempo in a performance of *Piano Phase*. The remaining pattern rates were selected to observe the effects of different tempi on listeners' perception of pulse. This also allowed the testing of Parncutt's "existence region of pulse sensation". Each sequence was cycled 12 times in order to resemble the approximate length of time listeners would be exposed to the pattern in a performance of the music.[13]

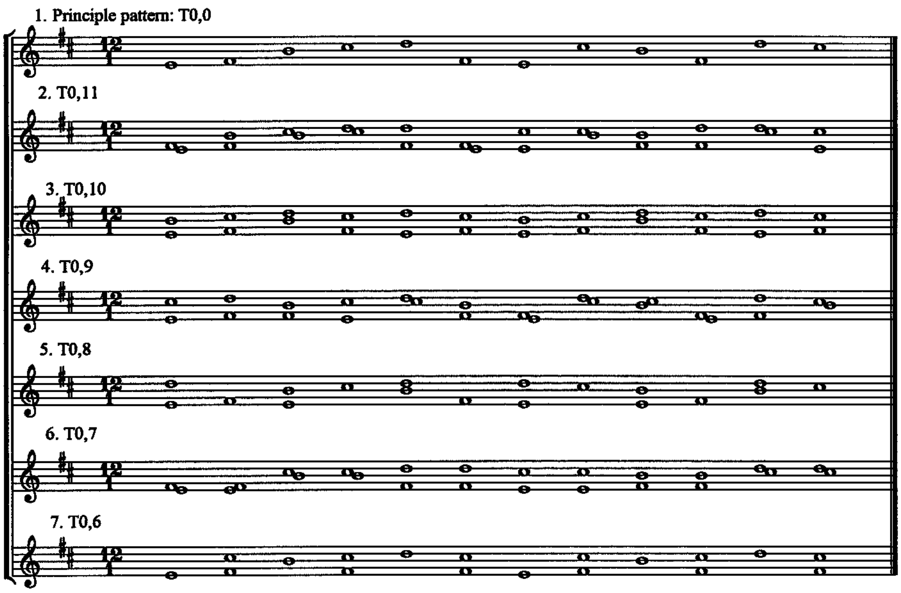
The majority of patterns in Figure 5-5 could be heard in either three groups of 4 beats, or two groups of 6 beats. The aim of the experiment was to investigate the extent of this metric ambiguity. It was predicted that certain regularities within the structure of each pattern would influence listeners' perception of pulse. Such regularities might include the dispersion of dissonant dyads ($T_{0,11}$; $T_{0,9}$ and $T_{0,7}$), or symmetrical characteristics of pitch structure ($T_{0,10}$; $T_{0,8}$ and $T_{0,6}$). Due to the structure of the principal pattern, all of the permutations notated above contain an 'E' on beat 1 and beat 6 of the cycle. In many cases, this distribution is expected to favour groupings of 6 beats. Less obvious regularities within the pattern structure

[13] The length of prolongation regions in section A of *Piano Phase* ranges from 12 to 24 bars.

however (which listeners may be attuned to), are expected to evoke a range of alternative responses.

Figure 5-5 Seven stimulus patterns used in the experiment

Notes are presented as whole tones so as not to imply perceived grouping.



Musical sequences were created on a Macintosh computer using an interactive software package, Max 3.5. All sequences were presented using a piano sound from a Kurtzweil 2000. The same volume level was used for all subjects, who heard the sequences through a set of high quality headphones.

Programming and Materials

The experiment was designed to be operated using a desktop computer. The software program introduced the participant to the experiment, controlled and presented stimuli, recorded the subject's taps and the order of trials, controlled the practice session, and provided step by step instructions. The program was developed by the researcher on a Power Macintosh computer (6300) using Max 3.5. Participants began each trial by clicking on a button with the mouse. Subjects tapped their pulses on the space-bar of the computer keyboard, which cued the program to record details regarding the distribution of taps. Specifically,

1. a virtual clock in Max 3.5 recorded the time (in milliseconds) of each tap from the start of the sequence with 5 ms accuracy; and
2. a virtual counter in Max 3.5 recorded which beats corresponded with a tap (indicated by a zero), and the time elapsed between taps.

All testing was conducted on the same computer, and all were carried out in the 'Electronic Music Studio', a facility provided by the School of Music and Music Education at the University of New South Wales. Although the room was not soundproofed, no disturbances were reported in Section D of the questionnaire, or noticed by the experimenter. All tests were conducted at times when the room, and neighbouring rooms, were unoccupied.

Three colleagues from the School of Music and Music Education (including the Head of the School of Music Education, and two doctoral candidates) carried out the experiment from beginning to end, prior to the period of testing, to test the program. No problems were experienced with the presentation of sequences, order of trials, collection of data, or any other aspect of the program.

The main components of the computer program, including the subjects' instructions and interface, musical sequences, the format of recorded data, and the order of trials are provided in Appendices E, F, G and H.

Procedure

Participants were tested one at a time. Each participant signed up for a 40 minute time-slot in which to complete the questionnaire, a short practice session, and the main experiment. At the commencement of each session, the researcher explained the opening screen of the experiment to the subject, who was then asked to follow the instructions on the screen. The experimenter sat outside the studio, and was available for help at anytime during the experiment.

The experiment was preceded by a short practice session, consisting of three practice trials, to familiarise the subject with the tapping procedure, and provide an opportunity to clarify the instructions if necessary. When the practice session was complete, the subject was asked to click a button with the mouse when they were ready to begin trial number one.

In each trial, the subject was asked to tap the space-bar of the computer keyboard in time with the underlying beat or pulse of each sequence. Subjects were instructed to begin tapping as soon as they identified a 'regular' pulse, and to continue tapping until the end of the sequence (after 12 repetitions of the cycle). The subject's knowledge of the difference between tapping out a pulse, and tapping out a rhythm, was established before the practice session began. No subjects had difficulty with this distinction. The sound of the tapping on the space bar was not considered to have influenced results, as subjects would have chosen a pulse prior to tapping it out (Parncutt, 1994). Temporal category boundaries for taps were set halfway between note onsets (sixteenth notes), a procedure which is consistent with categorical perception described by Clarke (1987).

Trials were presented in one of three orders (see Appendix G). The order was chosen automatically by the program when the experiment was initiated. The orders were constructed so that no two consecutive trials presented the same pattern or the same tempo. This was implemented to avoid metric carry-over effects from trial to trial. The order selected by the program was recorded for each subject. Order one was chosen four times, order two was chosen six times, and order three was chosen four times. A visual inspection of the data provided no evidence that subject responses were influenced by the order of trials.

The initiation of trials was controlled by the participant, who clicked a button with the mouse to start each new sequence. This was because the tapping task required that subjects were prepared for the onset of the sequence. No subjects reported having any difficulty using the mouse, or using the space-bar as an instrument for tapping pulses.

Results

The results reported below are divided into three sections. The first section reports the number of times different pulse trains were selected by subjects (specified by period and phase) in each trial. Throughout this section, pulse trains are expressed as P-Q. For example, if a subject tapped on every fourth beat of the cycle, the first tap falling on beat 1, then the pulse train is described as 4-1. The second section reports the average number of beats before subjects responded in each trial across the five presentation rates. In addition, it examines the difference between the performance of musicians and non-musicians. The third section of the results reports the average number of times subjects strayed from the beat. That is, it reports the number of times subjects' responses fell outside temporal category boundaries.

Period (P) and Phase (Q)

The tables presented throughout this section show the frequency with which different pulse responses were selected for each region.[14] The far left column denotes the period and phase (P-Q) selected, and columns 2 to 6 indicate the pattern rates from fastest to slowest. The total number of selections across all presentation rates is provided in the right hand column.

Table 5-3 Frequency of selected periods and phases for region $T_{0,0}$

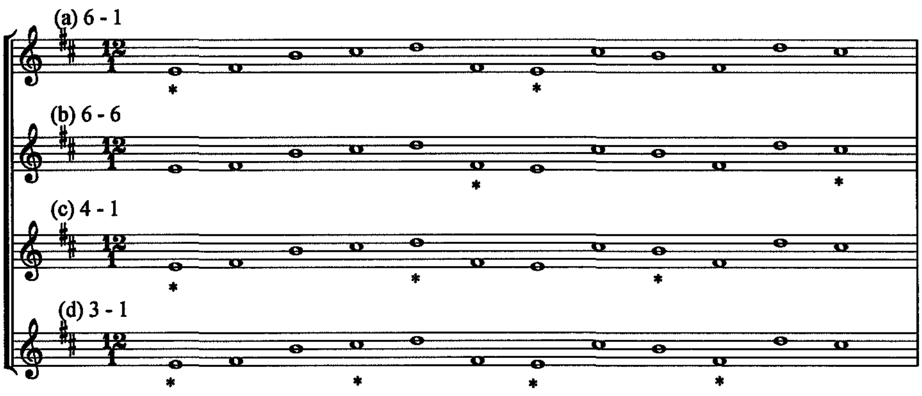
	139 ms	150 ms	200 ms	250 ms	300 ms	Total
2-1		2	3	5	5	15
2-2					1	1
3-1	2	1				3
4-1	1	1	1	1	1	5
4-3					1	1
6-1	10	10	9	8	5	42
6-6			1		1	2
12-1	1					1
						Sum =70

[14] In accord with Parncutt (1994), no inferential statistics were carried out. Rather, the number of times each pulse response was selected was taken as a measure of its perceptual salience. These results are compared with several aspects of Parncutt's (1994) model of pulse salience.

Table 5-3 shows the frequency of selected periods and phases for $T_{0,0}$ (the principal pattern). The results suggest that even before the phase-shifting process begins, the pattern is metrically ambiguous. That is, subjects heard this pattern in groups of 2, 3, 4, 6 or 12. While no subjects selected P=2 for the fastest sequence (139 ms), the slower sequences increased in this selection. In addition, the number of people who chose P=6 decreased systematically as tempo decreased. The pulse train 6-1 was selected by ten of the 14 participants in each of the two fastest tempos. Figure 5-6a, shows that this pulse train matches the regular distribution of E, on beats 1 and 6. In some cases, subjects did not perceive a downbeat on the E, but on the first F# (2-2), the B (4-3) or the second F# (6-6). Pulse trains 2-2 and 6-6 match the F#-C# sonority. The pulse trains 4-1, 3-1 and 6-6 (shown in Figure 5-6), selected by several subjects, display less regularity in the way pulses map onto the pitch structure. That is, they coincide with a variety of different notes, rather than with the repetition of a single note.

Figure 5-6 Selected pulse trains for the principal pattern ($T_{0,0}$)

For this, and all subsequent musical examples, asterisk indicates the notes which coincided with subjects' pulse responses (taps).



Although several subjects chose periods of 3 in the faster tempos, no groups of three were selected in the slower presentations of the sequence.

Table 5-4 Frequency of selected periods and phases for region $T_{0,11}$

	139 ms	150 ms	200 ms	250 ms	300 ms	Total
2-1	1	1	3	4	4	13
2-2			1	2	1	4
3-3	1	1	1		1	4
4-1	1		1	1		3
4-2		1				1
6-1	5	5	5	5	4	24
6-5	2					2
6-6	3	6	3	2	4	18
12-1	1					1
						Sum = 70

Table 5-4 shows the frequency of selected pulse-trains for region $T_{0,11}$. Once again, the tendency to select a period of 2 increased in the slower sequences. The number of subjects selecting periods of 6 (6-1 and 6-6) however, did not systematically decrease as pattern rate became slower. Only one subject chose a period of 12 at the fastest tempo. There was little difference between the number of people who chose 6-1 and 6-6 across all tempos. Figure 5-7 demonstrates that both of these templates correspond with the occurrence of E, and that downbeats coincide with dissonant pairs (E and F#). The selections 2-2 and 3-3 (example d.), both made on four occasions, coincide with a combination of high and low notes.

Figure 5-7 Pulse trains selected for $T_{0,11}$

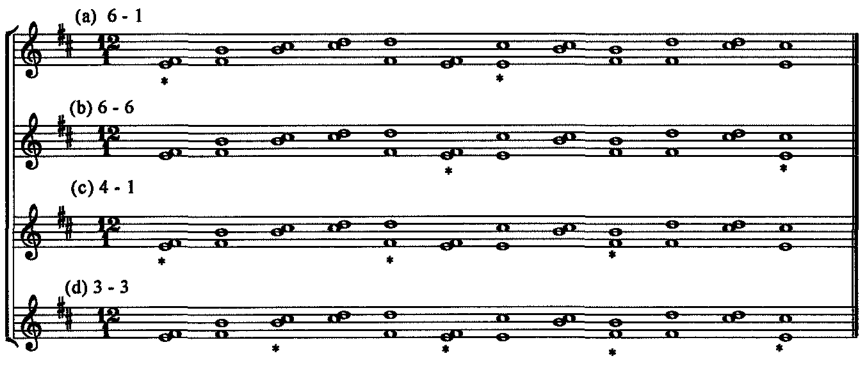


Figure 5-7c shows that the pulse train 4-1, selected on three occasions, coincides with the first F# of every consecutive pair. This result suggests that pulse train responses may be initiated by any number of regularities within the pattern structure.

Table 5-5 Frequency of selected periods and phases for region $T_{0,10}$

	139 ms	150 ms	200 ms	250 ms	300 ms	Total
2-1	2	2	5	5	8	22
2-2			1	1		2
4-1	2	2	1	2	1	8
4-4				1		1
6-1	9	9	7	3	5	33
6-4		1				1
6-5	1			1		2
6-6				1		1
						Sum = 70

The most frequent response in $T_{0,10}$ was period of 6, phase of 1. The structure of the pattern, which consists of two identical figures, increases the prominence of the 6-1 pulse sensation (see Figure 5-8). Despite the occurrence of the repeated figure however, eight people perceived the pulse train 4-1. Figure 5-8b shows that the second group of four is initiated by the recurrence of the E. Once again, the selection 2-1 (which may represent a smaller referent time level of 6-1 or 4-1) increases steadily in the slower sequences, while the selection P=6 decreases. A period of 6 was selected by five subjects at the slowest tempo. By contrast, two subjects chose a very rapid pulse at 139 ms, P=2. The other selections of P=6 corresponded with phases of 4, 5 and 6 (see Figure 5-8, examples c, d and e). Although the perceived downbeat varied among these selections, groupings of 6 beats dominated.

Figure 5-8 Pulse-trains selected for region $T_{0,10}$

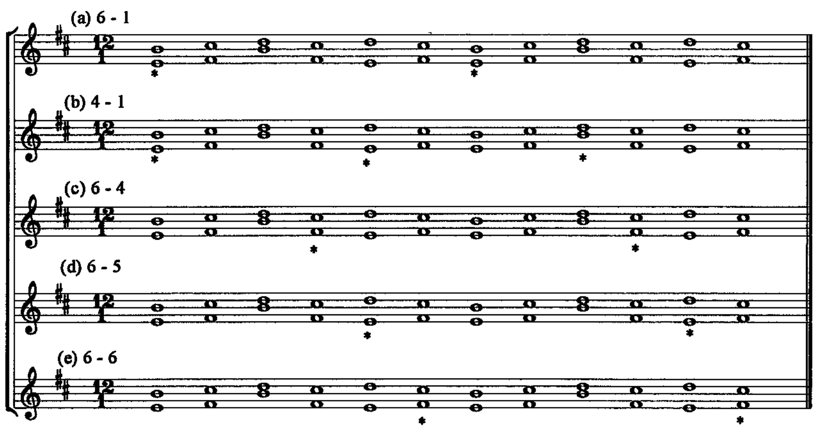


Table 5-6 shows the frequency of the selected pulse trains for region $T_{0,9}$. The results suggests that the probability of listeners grouping the pattern in groups of three is high. A pulse train of 3-1 was selected most frequently by subjects for all tempi.

Table 5-6 Frequency of selected periods and phases for region $T_{0,9}$

	139 ms	150 ms	200 ms	250 ms	300 ms	Total
2-1					2	2
2-2				1		1
3-1	10	12	10	11	7	50
3-2			2	1	2	5
3-3				1	1	2
4-1	1	1	1			3
6-1	2				1	3
6-4			1			1
12-1	1	1			1	3
						Sum = 70

Figure 5-9a shows that the pulse train 3-1 maps every occurrence of E. The pattern in this region generates an even distribution of E's from the first beat of the cycle. On five occasions, subjects selected a period of 3, phase of 2. Figure 5-9b shows that this template maps onto the regular occurrence of the D. On three occasions, subjects chose periods of 4, corresponding with the regular occurrence of C (see Figure 5-9c). Three subjects chose periods of twelve, tapping only once per cycle.

Figure 5-9 Pulse trains selected for region $T_{0,9}$

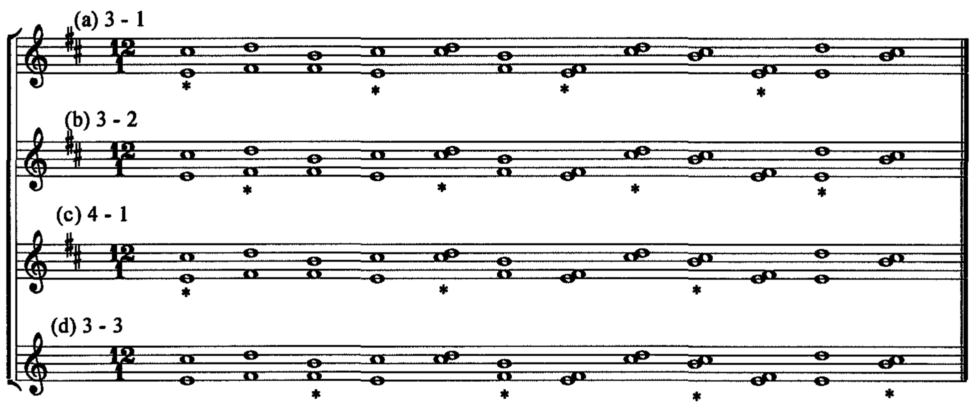


Figure 5-9d suggests that subjects who chose the pulse train 3-3 were attuned to the regular occurrence of B. Subjects who chose periods of 6 (6-1 or 6-4) tapped less frequently, in time with every second occurrence of the E.

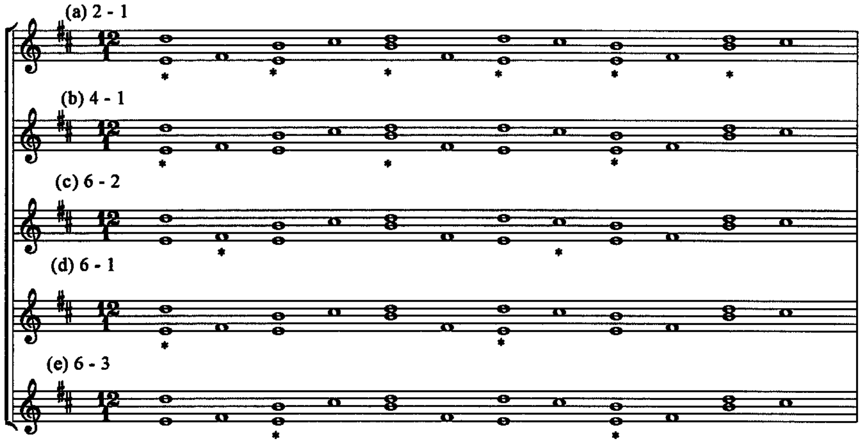
In comparison with other patterns, region $T_{0,8}$ induced more regular pulse sensations. The symmetry of this region (see Figure 5-10) suggests that several regularities within the pattern may have influenced the choice of pulse. Table 5-7 shows that even in faster sequences, subjects chose periods of two frequently. Therefore, the majority of selections were below moderate tempo.

Table 5-7 Frequency of selected periods and phases for region $T_{0,8}$

	139 ms	150 ms	200 ms	250 ms	300 ms	Total
2-1	2	4	8	9	9	32
2-2					1	1
4-1	2	3	1			6
6-1	4	2		4	3	13
6-2				1		1
6-3	6	5	4		1	16
6-6			1			1
						Sum = 70

The template 2-1 (see Figure 5-10a), which was selected most frequently in this region, maps the symmetrical pattern D-B-D. The tendency to select a period of 2 clearly increased as the pattern rate became slower. On six occasions, subjects preferred the grouping 4-1 (see Figure 5-10b). The results suggest that subjects who chose either 2-2 or 6-2 were attuned to the pattern formed by the alternation of F# and C# (see Figure 5-10c). The fact that these notes are doubled in unison by both instruments may have reinforced the salience of the corresponding pulse sensation. Selections of 6-1 and 6-3 are assumed to be a broader referent time level of 2-1, using E as a regular cue. On four occasions, subjects chose a period of 6 at 300 ms, representing a comparatively slow pulse-train.

Figure 5-10 Pulse trains selected for region $T_{0,8}$



In region $T_{0,8}$, the pulse train 6-3 was selected more often than 6-1, which was only chosen once. This suggests that the note E in combination with B initiated a stronger downbeat than E in combination with D (see Figure 5-10d and 5-10e).

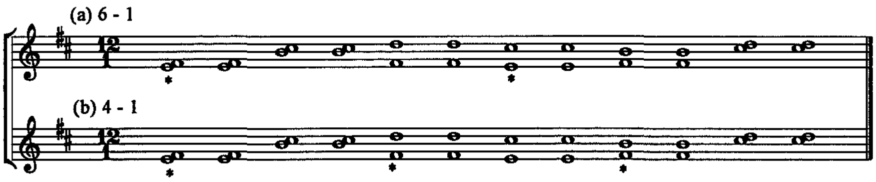
Table 5-8 shows the results for $T_{0,7}$. In this region, more periods of 12 were selected than in any other region, particularly at the three fastest presentation rates. Interestingly (with the exception of $T_{0,8}$), the pattern in $T_{0,7}$ also evoked more periods of 2 than any other region. The number of times subjects selected periods of 2 increased at slower presentation rates.

Table 5-8 Frequency of selected periods and phases for region $T_{0,7}$

	139 ms	150 ms	200 ms	250 ms	300 ms	Total
2-1	2	5	7	7	7	28
2-2				1		1
3-1	1					1
4-1	2	1	2	1	3	9
6-1	8	5	3	4	2	22
12-1	1	3	2	1	1	8
						Sum = 70

In $T_{0,7}$, the pulse train 6-1 maps the first dyad of each pair containing the note E, while the pulse train 4-1 corresponds with the first dyad of each pair containing an F# (see Figure 5-11).

Figure 5-11 Pulse trains selected for region $T_{0,7}$



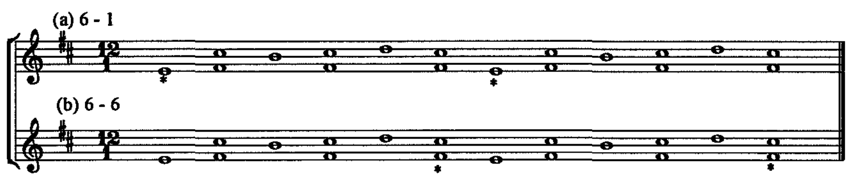
As shown in Table 5-9, the most salient pulse sensation in region $T_{0,6}$ was 6-1, mapping the two E's that occur in the cycle (see Figure 5-11a). It was rare for subjects to feel the pulse in groups of 4 (only three occasions).

Table 5-9 Frequency of selected periods and phases for region $T_{0,6}$

	139 ms	150 ms	200 ms	250 ms	300 ms	Total
2-1	1	2	4	6	4	17
2-2		1	1	1	3	6
3-1	1					1
3-3		1				1
4-1	1	1	1		1	4
4-3				1		1
6-1	9	9	6	5	5	34
6-6	1		2	1	1	5
12-1	1					1
						Sum = 70

On five occasions however, subjects chose the pulse train 6-6, where the downbeat coincides with the F#-C# sonority (see Figure 5-12b). The choice of the pulse train 2-1 is assumed to represents a smaller division of 6-1, and the selection 2-2, a smaller referent level of the pulse train 6-2 (corresponding to every occurrence of the F# - C# combination). Groups of 3 were chosen on two occasions only for this region. As shown in Table 5-9, the tendency for periods of 2 to increase with faster pattern rates, and periods of 6 to decrease, was apparent in this region.

Figure 5-12 Pulse trains 6-1 and 6-6 for region $T_{0,6}$



Several trends can be established by collapsing the data across all patterns and tempos. A total of 162 different pulse responses were collected in the experiment. The total number of *different* responses in each region, in order, is 21, 28, 22, 23, 19, 23, and 26. Overall, the number of selections clearly suggest that pulse perception in *Piano Phase* is ambiguous. As a function of pattern rate, the number of different selections (from fastest to slowest) is 34, 29, 31, 32, and 33. These figures do not suggest that ambiguity (the number of different selections) increased with pattern rate.

The relationship between pattern rate and the choice of pulse-train was assessed by counting the number of times subjects selected periods of 2 and periods of 6. Table 5-10 shows a systematic increase in the number of times subjects selected periods of two as the tempo decreased. By contrast, the number of times subjects selected periods of 6 (less regular pulse trains) decreased systematically as pattern rate decreased.

Table 5-10 Total number of times subjects selected periods of 2 and 6

	139ms	150ms	200ms	250ms	300ms
P=2	8	17	33	42	46
P=6	60	52	41	32	35

Number of beats elapsed before first tap

Table 5-11 shows the average number of beats in the pattern cycle before subjects responded in each trial. The figures in the far right hand column show the mean of the average number of beats before subjects responded as a function of tempo. The results indicate that the average number of beats before subjects responded decreased systematically with pattern rate.[15]

[15] These results may be explained by the tendency for subjects to select more regular pulse trains at slower tempos. That is, subjects did not have to wait as long to begin tapping once they had identified a pulse for slower sequences.

Table 5-11 Average number of beats elapsed before first tap

	$T_{0,0}$	$T_{0,11}$	$T_{0,10}$	$T_{0,9}$	$T_{0,8}$	$T_{0,7}$	$T_{0,6}$	Mean of Averages
139 ms	18	24.14	21.57	17.57	20	20.57	17.57	19.92
150 ms	13.71	25.86	18.93	14.21	20.14	20.86	14	18.24
200 ms	12.79	17.71	13.07	17.64	14.07	17.29	12.57	15.02
250 ms	13.36	18.86	14.64	13.29	11.79	15.5	10.29	13.96
300 ms	12.64	15.36	11.86	11.79	13.07	13.79	12.71	13.03
Total	70.5	101.93	80.07	74.5	79.07	88.01	67.14	

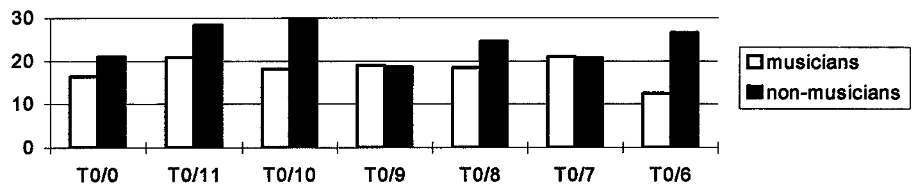
A repeated measures analysis of variance with two within subject factors (pattern and tempo) and one between-subject factor (musicians and non-musicians) revealed a significant main effect ($p<.05$) for tempo. For pattern $T_{0,0}$, significant differences ($p<.05$) were found between the fastest and the slowest tempi. For pattern $T_{0,11}$, significant differences ($p<.05$) were found between 139 ms and 300 ms, 139 ms and 250 ms, 150 ms and 300 ms, and 150 ms and 200 ms. For pattern $T_{0,10}$, significant differences ($p<.05$) were found between 139 ms and 300 ms, and 150 ms and 300 ms. For pattern $T_{0,9}$, a significant difference ($p<.05$) was found between the fastest and slowest tempi only. For $T_{0,8}$, a significant difference was found between 139 ms and 300 ms, 139 ms and 250 ms, and 139 ms and 200 ms. In addition, the second fastest tempo (150 ms) was found to be significantly different from 250 ms and 300ms. For $T_{0,7}$, tempo 139 ms was found to be significantly different ($p<.05$) from 300 ms and 250 ms. The second fastest tempo (150 ms) was also found to be significantly different from 300 ms and 250 ms. For pattern $T_{0,6}$, the fastest tempo was found to be significantly different from 300 ms and 250 ms. Taken together, these results suggest that the tempo of each sequence has an influence on the time taken for listeners to tap a pulse response.

Table 5-11 suggests that it took longer for subjects to locate a pulse for pattern $T_{0,11}$ than other patterns. This concurs with the results for period and phase, which showed that $T_{0,11}$ evoked the widest variety of pulse-train responses overall. The analysis of variance revealed a significant ($p<.05$) main effect for pattern. Paired comparisons revealed significant differences between $T_{0,11}$ and $T_{0,0}$ for all tempi except 300 ms. For three presentation rates (139 ms, 150 ms and 250 ms), a significant difference ($p<.05$) was also found between patterns $T_{0,11}$ and $T_{0,6}$. No significant differences were found between patterns for the slowest tempo. These differences suggest that the type of pattern has a bearing on how long it takes listeners to tap a pulse response.

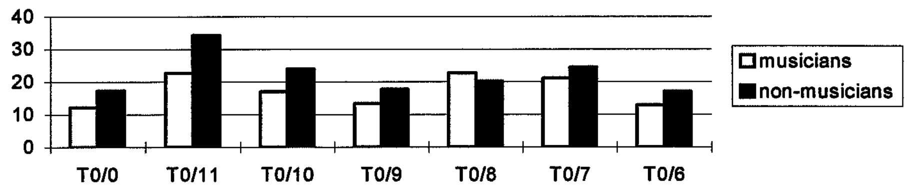
Figure 5-13 demonstrates that musicians responded more quickly than non-musicians in 29 of the 35 trials (83% of cases). The six exceptions occurred in regions $T_{0,9}$ and $T_{0,7}$ (139ms); $T_{0,8}$ (150ms); $T_{0,10}$ (200ms); $T_{0,8}$ (250ms); and $T_{0,10}$ (300ms).

Figure 5-13 Average number of beats before subjects responded

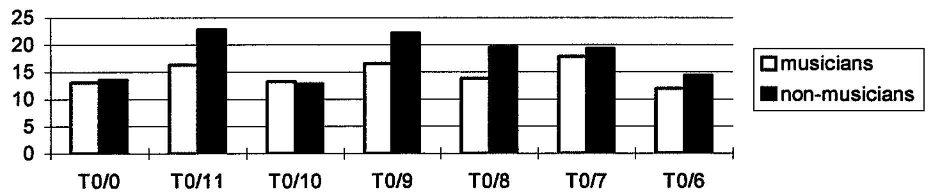
a. 139 ms



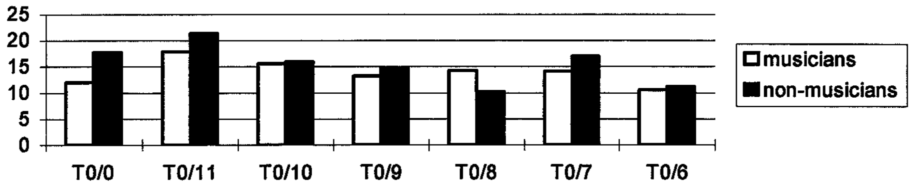
b. 150 ms



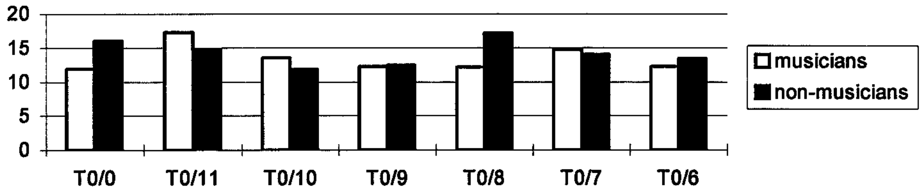
c. 200 ms



d. 250 ms



e. 300 ms



Although the means suggest that musicians responded more quickly than non-musicians in most cases, the main effect for musicians and non-musicians was not found to be significant. However, paired comparisons did reveal significant differences (p<.05) between musicians and non-musicians for tempi 139 ms (T0,0, T0,10 and T0,6), 150 ms (T0,0 and T0,10), 250 ms (T0,0) and 300 ms (T0,0).

Deviations

A deviation was counted when subjects' pulses strayed more than half a beat away from the selected pulse-train, that is, when the position of the tap fell outside the temporal category boundary. The number of deviations generally increased as the tempo of the sequences decreased. In faster sequences, subjects usually selected broader referent time levels. Therefore, their ability to adhere to the beat may have been assisted by smaller divisions of the referent level (articulated by notes of the pattern). The attention of the listener may also have had a significant effect on the number of times they exceeded temporal category boundaries.

Discussion

Experiment 1A was devised to test six assumptions related to the perception of pulse in the prolongation regions of Reich's *Piano Phase*. The first assumption was that subjects would exhibit a diverse range of pulse responses in each region. This was supported by the results of the experiment, which showed that pulse perception in the prolongation regions of *Piano Phase* is highly ambiguous. Results show that a high number of period and phase combinations were selected by subjects. Periods of 4 and 6 were selected in all regions. Other periods represented smaller or broader referent time levels of 4 or 6. The level of ambiguity demonstrated in the experiment supports the notion of the 'free play' of the musical system (introduced in Chapter 2), and consequently, the idea that the experience of temporality in Reich's music is highly varied for different listeners.

The second assumption was that pulse trains matching the greatest number of note onsets would be more salient. In accord with existing research (Lerdahl & Jackendoff, 1983; Longuet-Higgins & Lee, 1984; Povel & Essens, 1985), the results of Experiment 1A showed that listeners' pulses coincided with note onsets in particular ways. For example, the most salient pulse sensations tended to map regularities in each pattern, such as the regular dispersion of a particular note. The fact that periods and phases varied widely within and between patterns, however, can be attributed a wide range of pattern regularities which exist within each pattern. Therefore, the most salient pulse sensation may depend on which pattern regularity is perceived as dominant.

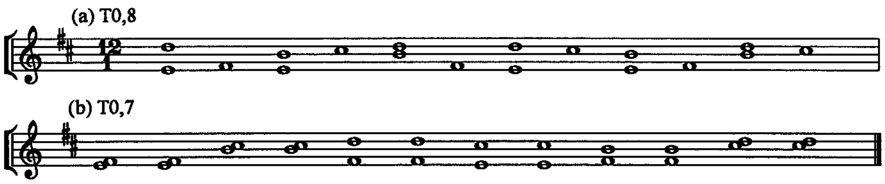
Although the $T_{0,9}$ pattern induced strong groupings of three (mapping the regular occurrence of E), several subjects heard the pattern in groups of four. This suggests that even strong regularities within the structure of patterns can be counteracted by other factors influencing the sensation of pulse.

The third assumption was that the majority of pulse sensations would fall within the dominance region of pulse salience (400-900 ms), and that all pulse sensations would fall within the existence region of pulse sensation. On many occasions, the results of the experiment contradicted the 'existence region of pulse sensation' as defined by Parncutt (1994), which states that pulse sensations cease to exist at rates faster than 200 ms and slower than 1800 ms. Often, the results rested on the perimeter of the existence region, and on several occasions, pulses fell outside the region. For example, in region $T_{0,11}$, the pulse train 2-1, selected by one subject at 139 ms, falls just within the region. Period intervals for region $T_{0,6}$ ranged from 278 ms to 1800 ms. In regions $T_{0,11}$, $T_{0,10}$, $T_{0,9}$, $T_{0,8}$, and $T_{0,7}$, slower tempos induced periods of 1800 ms, once again, resting on the border of the existence region. On four occasions (in $T_{0,9}$ and $T_{0,7}$), subject's responses fell outside the existence region of pulse sensation. In region $T_{0,9}$, one subject selected a period of 12 for the slowest tempo. At 300 ms, a period of 12 well exceeds the existence region of pulse sensation, one tap occurring every 3600 ms (every 3.6 seconds). Half way through the sequence, however, the subject doubled the pulse rate to a period of 6, suggesting that pulse sensations could not be maintained at such a slow rate.

The results for $T_{0,7}$ present a special case. Due to the structure of the pattern, which consists of a series of repeated dyads, subjects tended to choose very broad referent time levels. On eight occasions, the pattern evoked periods of 12, despite the fact that for all tempos except 139 ms, the pulse sensations fall on or outside the existence region of pulse sensation. That is, pulse sensations were separated by 1800 ms, 2400 ms, 3000 ms, and 3600 ms respectively.

For these reasons, I argue that in more complex musical stimuli, the existence region of pulse salience needs to be broadened to accommodate certain characteristics of pattern structure, in particular, for patterns which can be easily broken down into much smaller units. Evidence that smaller units were salient in $T_{0,7}$ can be found in the equally high number of subjects who chose periods of two. This can be explained by the strong subjective accents which occur on every second beat of the pattern. For similar reasons, the pulse train 2-1 was particularly salient in $T_{0,8}$. As shown in Figure 5-14a, $T_{0,8}$ consists of an alternating pattern of two-note chords and unisons. The consistency of this alternation evokes strong subjective accents on every second beat. Similarly, the structure of $T_{0,7}$ (Figure 5-14b) falls into a series of repeating dyads, increasing the salience of the pulse train 2-1.

Figure 5-14 Patterns $T_{0,8}$ and $T_{0,7}$



Parncutt (1994) suggests that pulse sensations slower than 1800 ms may be explained as a phenomenon related to musical form rather than rhythm. This alternative explanation is feasible, although it should be noted that the subjects exceeding this boundary were not familiar with the excerpts presented in the experiment.

The results for the fourth assumption demonstrated that slower sequences tended to evoke more regular pulse trains, and faster sequences tended to evoke less regular pulse trains. That is, pulse responses tended to gravitate toward moderate tempo. This trend was clearly apparent for regions $T_{0,0}$; $T_{0,10}$; $T_{0,7}$; and $T_{0,6}$, where the number of times subjects selected periods of two systematically increased for slower tempos. In addition, it was shown that periods of six systematically decreased for slower tempos. In region $T_{0,9}$, the majority of subjects chose periods of three despite the presentation rate. This result concurs with Handel and Lawson (1983) and Parncutt (1994), because the results fall within the range of moderate tempo. Specifically, the distance between pulse sensations in this region, for periods of three, ranged from 417-900 ms.

The fifth assumption was that any repetition in a pattern would act as a metrical cue. As suggested earlier in the discussion, subjects' responses tended to match certain regularities in pattern structure (such as the regular dispersion of single notes). Other types of symmetry, based on repetition, were also shown to influence pulse responses. For example, in the prolongation regions consisting of two repeated six-beat figures ($T_{0,10}$ and $T_{0,6}$), the most salient pulse sensation was 6-1. The choice of phase, however, varied between 2, 3, 4 and 5. Importantly, the wide range of phases suggests that while the repetition of figures may act as a significant metrical cue, the downbeat will not necessarily be heard on the first beat of the pattern.

The sixth assumption was that doubled attacks occurring within a pattern would increase the salience of pulse sensations. In the musical analysis, presented in Chapter 4, a 'doubled attack' occurred when two notes from the same registral stream occurred on the same beat. The results showed that low dissonant dyads (E/F#) in patterns $T_{0,11}$; $T_{0,9}$; and $T_{0,7}$ tended to coincide with the most commonly selected pulse-trains. High doubled attacks (C#/D) however, rarely coincided with the most commonly selected pulse trains. This suggests that while doubled attacks may have increased the salience of pulse sensations matching notes of the low stream, they did not act as a strong metrical cue.

As demonstrated in the discussion above, the results of Experiment 1A demonstrated similarities with existing research on a number of levels. For example, pulse responses tended to gravitate toward moderate tempo, and factors such as repetition and pattern regularity tended to influence the salience of pulse sensations. While subjects' responses did not always fall within the existence region of pulse sensation, the majority of results reflected these boundaries. In particular, the results of Experiment 1A demonstrated that, due to the nature of the phase-shifting process, any number of regularities that exist within the structure of each pattern may influence the listeners perception of pulse. This accounts for the highly ambiguous nature of pulse perception in *Piano Phase.*

Experiment 1B: Pulse perception of individual streams in *Piano Phase*

Theoretical Background

Experiment 1A showed that listeners' perception of pulse in each region was influenced by certain tempo dependent regularities within the pattern structure. In order to demonstrate that the range of pattern possibilities in this music contributes to the ambiguity of pulse perception, the next step was to explore listeners' perception of pulse for individual streams. According to the principles of stream segregation, listeners are likely to attend to either the high or low patterns generated in each region of *Piano Phase*.

I argue that stream segregation has a significant bearing on listeners' perception of pulse in the sense that it will depend on which of the available streams is held in awareness. This suggests that rhythmic ambiguity will be more prominent when the high and low streams generate conflicting pulse-trains. Consequently, a second experiment was required to examine the perception of pulse in resulting (registral) patterns, in order to assess the extent of this conflict. In Chapter 4, I stated that during the course of listening, listeners may switch their attention (consciously or not) between registral streams. For this reason, the salience of pulse sensations for individual streams has a significant bearing on the nature of temporality in this music, which relies heavily on the attention of the listener.

It is assumed that if a listener attends specifically to either the high or the low patterns in *Piano Phase*, then pulse responses for global patterns (in Experiment 1A) will resemble those selected for individual streams. Alternatively, the metric framework of one stream might accommodate the rhythmic pattern generated by the other. Bregman (1990) states that the temporal relations between streams is lost when segregation occurs, although this loss may not be total. The results collected for period and phase in this experiment are compared with the results of Experiment 1A to see if pulse responses for the high or low stream correspond with the most commonly selected pulse trains for global patterns.

Aim

Experiment 1B tested listeners' perception of pulse in the high and low resulting patterns of *Piano Phase*. The aim of the experiment was to calculate the most salient pulse sensations for the high and low resulting patterns in each region. An additional aim was to investigate any correspondence between the salience of pulse sensations for global patterns (Experiment 1A) and individual streams.

Methodology

Subjects

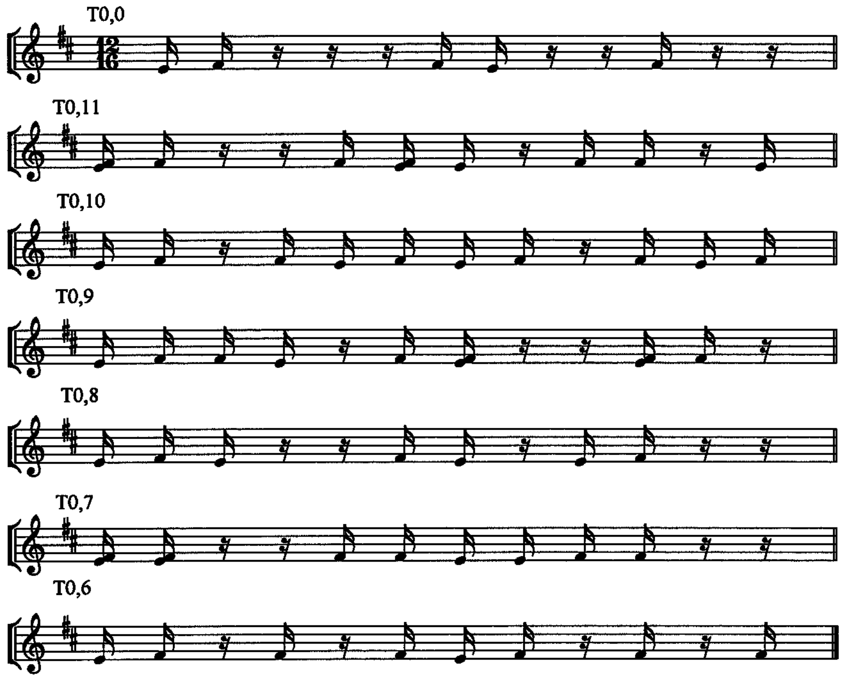
Fourteen subjects participated in the experiment, all of whom took part in Experiment 1A. A minimum of one month separated Experiments 1A and 1B to minimise learning effects.

Stimuli

As shown in Figure 5-15, the stimuli used in the experiment divided the global patterns (used in Experiment 1A) into their high and low registral streams. Only one note rate was used in the experiment, which matched the recommended tempo for *Piano Phase* (139 ms). The duration of each sound event was 89 ms.

Figure 5-15 Stimulus patterns used in Experiment 1B

Notes are unbeamed so as not to imply perceptual grouping.



As for Experiment 1A, the sequences, presented through headphones, were cycled twelve times in order to reflect the approximate length of time listeners would be exposed to the pattern in a performance of the music. The same piano sound (from a Kurtzweil 2000) was used, and the volume was kept constant for all experimental sessions. In accord with Experiment 1A, sequences were created on an Apple Macintosh computer using the software Max 3.5.

Programming and Materials

The program for Experiment 1B was designed to present the instructions of the experiment, control and present the fourteen stimulus patterns, record the timing of subject's taps, and record the order of presentation of trials. The program was developed on a Power Macintosh (6300) using the software Max 3.5 which collected the time of each tap from the start of each sequence, and recorded which beats corresponded with a tap. This allowed the researcher to gauge the time elapsed between subject's taps. Responses were recorded with 5 ms accuracy. The same computer and testing room was used for both Experiments 1A and 1B. The instructions for the experiment, and the display screen viewed by subjects are outlined in Appendix E.

Procedure

Subjects were tested individually during a 20 minute time-slot. As the same group of subjects were tested for Experiments 1A and 1B, the details collected in the original questionnaire were used to inform the results of Experiment 1B. Similarly, as the subjects were familiar with the tapping procedure, no practice sessions were conducted prior to the experiment. After reading the instructions on the opening screen, subjects were cued by the computer to click a button on the display to begin trial number one. In each trial, the subject was instructed to tap the space-bar of the computer to the underlying beat or pulse of each sequence. They were instructed to begin tapping the moment they identified a regular pulse, and to continue tapping until the end of the sequence.

In contrast to Experiment 1A, the order of trial presentation was different for each subject. The random order was controlled by the experimental program, and recorded in a separate file. Subjects clicked a button on the display screen to initiate each new trial.

Results

Period (P) and Phase (Q)

Table 5-12 shows the frequency of selected pulse trains for the set of high patterns. The left hand column specifies the selected pulse train. Columns 2 to 7 show the number of times each pulse train was selected for each pattern.

Table 5-12 Frequency of selected pulse-trains for the set of high patterns

	$T_{0,0}$	$T_{0,11}$	$T_{0,10}$	$T_{0,9}$	$T_{0,8}$	$T_{0,7}$	$T_{0,6}$
2-1			1		2	2	
2-2	1						
3-3	1		1	6		2	3
4-1	2	1		3	8	2	
4-2		1					
4-3	1	2				1	
4-4	2			1	2		1
6-1			2		1		1
6-2		5	2				3
6-3	2	3	5			2	6
6-4		2					
6-5	2			1			
6-6	1		3	1	1		
12-2						1	
12-3						3	
12-5	1					1	
12-8				1			
12-11				1			

The total number of different pulse train responses for the high stream over all regions was 46, suggesting a high degree of rhythmic ambiguity. Table 5-12 indicates that the high pattern in $T_{0,0}$ evoked a range of pulse-train responses spanning periods of 2, 4, 6 and 12. Two of the fourteen subjects selected a phase of 1 (period of 4), the downbeat of which falls on a rest. The remaining subjects chose phases of 2, 3, 4, 5 and 6.

The pulse train 2-2 was only selected by one subject in $T_{0,0}$. The salience of the pulse sensation 2-2 is not considered to be strong, because three pulses coincide with rests, and three with note onsets. The three notes that coincide with pulses are all C's, suggesting that less obvious regularities in the pattern structure are capable of enhancing the salience of pulse sensations. In $T_{0,0}$, one subject alternated between a period of 7 and 6, which progressed gradually through all phases (due to its uneven relationship with the 12-beat cycle).[16]

[16] This accounts for the first column adding up to 13 instead of 14.

In region $T_{0,11}$, the majority of subjects chose periods of 6, however their choice of phase varied (6-2, 6-3 and 6-4). Each of these choices correspond with two sounded beats per cycle (see Figure 5-16). No subjects chose periods of 2, but periods of 4 were selected by four subjects (including phases of 1,2, and 3). The most frequently selected pulse train in this region (6-2) corresponded with the first sounded beat of the cycle.

Figure 5-16 Selected pulse trains for the high pattern in region $T_{0,11}$

A diverse range of pulse-trains were selected for the high pattern of $T_{0,10}$. Subjects chose periods of six most frequently, covering all phases except 4 and 5 (see Figure 5-17)

Figure 5-17 Pulse trains selected for the high pattern in $T_{0,10}$

The symmetry of the high pattern in this region, which is defined by two repeated figures of six beats, increased the likelihood that periods of six would be selected. The position of the period relative to the start of the sequence however, is open to interpretation. No subjects chose periods of four for this region, and only one subject heard the pattern in groups of 3.

In region $T_{0,9}$, the pulse train 3-3, selected by 6 subjects, maps all sounded beats (see Figure 5-18a). Despite the fact that the first sounded beat of the pattern falls on the first beat of the cycle, no subjects chose the pulse train 6-1. The second most frequently selected response, 4-1, corresponds with all attacked beats (Figure 5-18b). Only two subjects chose periods of 6 in this region, both of which map note onsets. The pulse train 6-5 coincides with the doubled attack on beat five.

Figure 5-18 Pulse trains responses for the high pattern in $T_{0,9}$

The high pattern in region $T_{0,8}$ produced unique results. It is the only region in which periods of 4 dominated the selection. In this region, eight subjects chose 4-1, and two subjects chose 4-4. These selections are highlighted in Figure 5-19. Despite the strong tendency for groupings of 4, two subjects tapped every 6 beats (6-1 and 6-6).

Figure 5-19 Pulse train responses for the high pattern in $T_{0,8}$

The results for region $T_{0,7}$ are notably diverse. No more than 3 subjects tapped the same pulse train. Periods included 2, 3, 4, 6 and 12, and phases spanned 1, 2, 3 and 5. Five subjects in this region only tapped once per cycle (12-2, 12-3, and 12-5). The high number of people selecting a period of 12 is consistent with the results for this region obtained in Experiment 1A. The pulse train 12-3, the most frequently selected pulse, coincides with the first sounded beat of the pattern, also a doubled attack.

Periods of 6 were selected most frequently for the high pattern in $T_{0,6}$. Different phase selections coincided with different pattern regularities, such as the regular dispersion of C, or the regular dispersion of B (see Figure 5-20). One subject chose the pulse train 6-1, which maps the two rests present in the sequence. Despite the strong tendency for subjects to respond to the symmetry of the pattern, which consists of two repeated figures of six beats, one subject selected the pulse train 4-4.

Figure 5-20 Most commonly selected pulse trains in $T_{0,6}$

The results for the set of low patterns are summarised in Table 5-13. The number of different responses overall was 38, which is less than the number of different responses evoked by the high patterns (46 different responses).

Table 5-13 Frequency of selected pulse trains for the set of low patterns

	$T_{0,0}$	$T_{0,11}$	$T_{0,10}$	$T_{0,9}$	$T_{0,8}$	$T_{0,7}$	$T_{0,6}$
2-1	1			1			1
3-1	2	1		9	1	1	1
3-2			1				
3-3		1					
4-1				1	1		
4-2					1		
4-3					1		
4-4							1
4-5						1	
6-1	5	3	6	1	3	7	8
6-2			5				1
6-3					4		
6-4				1			
6-6	5	8	2	1	1	1	
12-1					2	4	2
12-7	1						

The low sequence derived from the principal pattern of *Piano Phase* ($T_{0,0}$) evoked an equal number of selections for 6-1 (coinciding with both E's) and 6-6 (coinciding with one F#). The selection 6-6, selected by five subjects, only coincides with one note onset. Remaining subjects chose more regular pulse-trains (2-1 and 3-1). No subjects chose groupings of 4.

The most common response for $T_{0,11}$ was 6-6, the pulses of which correspond with the regular occurrence of E. Three subjects chose 6-1, corresponding with the alternative distribution of E. In $T_{0,11}$, one subject selected a period of 10, which progressed systematically through all phases as a result.

The most common selections for region $T_{0,10}$ were 6-1 and 6-2, mapping the set of E's and F#'s respectively (see Figure 5-21). Periods of four were not selected by any subjects.

Figure 5-21 Most common selections for the low pattern in region $T_{0,10}$

The low pattern in region $T_{0,9}$ generated the fewest number of different responses. Nine subjects chose the pulse train 3-1, which corresponds with every occurrence of the E, two of which are doubled by the F# (see Figure 5-22). Two subjects felt the sequence in duple time (2-1 and 4-1), despite the fact that several pulses coincided with rests (2 and 4 respectively).

Figure 5-22 Pulse train 3-1 in region $T_{0,9}$

In region $T_{0,8}$, subjects felt the sequence in groups of 6 beats, although their downbeats varied. The pulse trains 6-1 and 6-3 both correspond with the dispersion of E's (see Figure 5-23). The first two notes of the pattern in example (b) would be perceived as an anacrusis, where the down beat falls on beat three of the cycle. Two subjects tapped only once per cycle (12-1).

Figure 5-23 Most common responses for region $T_{0,8}$

The results for the global patterns (experiment 1A) and high patterns showed that periods of twelve were selected more commonly in $T_{0,7}$ than in any other region. Similarly, the low pattern in the same region prompted four subjects to tap only once per cycle. The majority of subjects, however, tapped twice per cycle in this region (6-1), the first beat of which is reinforced by a doubled attack (see Figure 5-24).

Figure 5-24 Pulse train 6-1 in region $T_{0,7}$

The results for $T_{0,6}$ show a clear bias for groupings of 6, once again, corresponding with the set of E's. One subject chose the pulse train 6-2, corresponding with a set of F#'s (see Figure 5-25). Two subjects selected a period of 12, tapping only once per cycle. The selection 3-1 in this region maps the alternation of E and F#. The selection 4-4, selected by one subject, only corresponds with one sounded beat (the first note of the cycle).

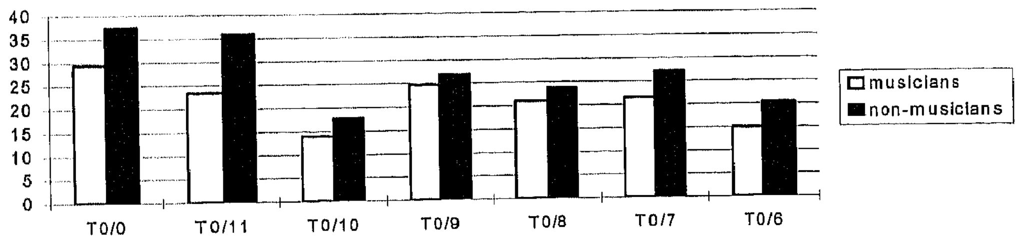
Figure 5-25 Selected pulse trains for the low pattern in $T_{0,6}$

Number of beats elapsed before first tap

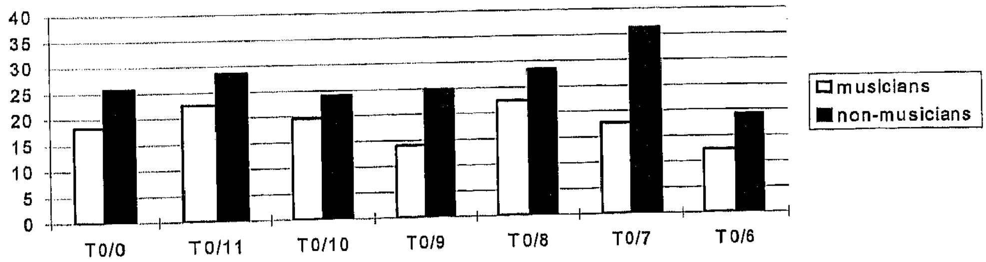
Figure 5-26 shows the average number of beats elapsed before subjects began tapping a pulse in each trial. A repeated measures ANOVA revealed a significant main effect ($p<.05$) for musicians and non-musicians for both high and low patterns.

Figure 5-26 Average number of beats before subjects responded: musicians and non-musicians

a. High stream



b. Low stream

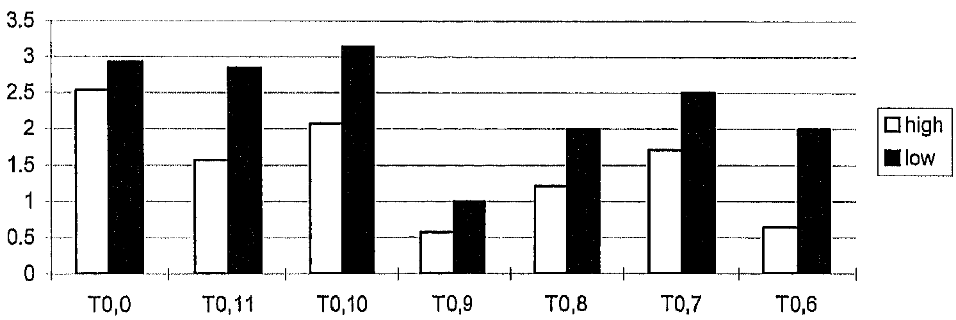


The main effect for pattern type was also found to be significant ($p<.05$) for both high and low patterns. For the high patterns, significant differences were found between $T_{0,10}$ and every other pattern except $T_{0,6}$. Significant differences ($p<.05$) were also found between patterns T0,0 and T0,6; T0,0 and T0,8; T0,11 and T0,8; and T0,11 and T0,6. For the low patterns, significant differences ($p<.05$) were found between T0,6 and every other pattern except T0,9. Once again, these results indicate that the type of pattern has a bearing on how long it takes for listeners to begin tapping a pulse response.

Deviations

Figure 5-27 shows the average number of times subjects deviated more than half a beat from the selected pulse-train for high and low patterns. The mean results show that subjects deviated from the template more frequently when tapping a pulse along with the set of low patterns than the set of high patterns. This was supported by a repeated measures ANOVA which revealed a significant main effect ($p<.05$) for the type of pattern (high or low).

Figure 5-27 Average number of deviations for the high and low patterns



Discussion

As in Experiment 1A, the results indicated that the most salient pulse sensations tended to match the greatest number of note onsets. Conversely, pulse-trains which coincided with one or more rests were found to be less salient (for example, T0,0, high pattern, 4-1; and T0,0, low pattern, 6-6).

Parncutt (1994) states that the greater the IOI after a sound event, the greater its perceptual salience, and consequently, the greater its role in the formation of pulse sensations. That is, notes occurring just prior to rests have a greater subjective accent, and for this reason, they are more likely to be perceived as downbeats or metrical accents. In terms of the most commonly selected pulses, Experiment 1B indicated that this was often the case (for example, in both the high and low patterns $T_{0,0}$; $T_{0,9}$ and $T_{0,8}$).

Several theories of meter perception (Longuet-Higgins & Steedman, 1971; Steedman, 1973, 1977; Longuet-Higgins & Lee, 1982; Lee, 1985) suggest that processing considerations should be taken into account when considering listener's perception of pulse or meter. That is, they argue that the listener's final choice of interpretation for a sequence depends on the series of metrical judgements made during the course of listening. In a performance of *Piano Phase*, the listener's initial interpretation of pulse in prolongation regions would depend on their metric orientation (or disorientation) coming out of the accelerating regions. I argue however, that once the two pianos re-synchronise, the degree of repetition of patterns in the prolongation regions would serve to remove the emphasis from the first (notated) beat of the cycle as a metrical cue. This is suggested in the results of Experiment 1B, which demonstrated that listeners selected phases other than 1, even when the first beat of the cycle coincided with a note onset (for example, $T_{0,10}$ and $T_{0,9}$, high stream; $T_{0,11}$ and $T_{0,8}$, low stream).

The musical analysis of *Piano Phase*, presented in Chapter 4, examined the rhythmic dispersion of doubled attacks. Experiment 1B demonstrated that in regions containing doubled attacks ($T_{0,11}$, $T_{0,9}$ and $T_{0,7}$), the most salient pulse sensations coincided with at least one doubled attack. In $T_{0,9}$, the most salient pulse sensation (3-3) coincides with two evenly dispersed doubled attacks. These results suggest that the dispersion of doubled attacks in *Piano Phase* has some bearing on the salience of pulse sensations.

The periods selected in Experiment 1B generally fell well within the existence region of pulse sensation defined by Parncutt (1994). Subjects were less likely to choose more regular pulse trains (periods of two at 139 ms) for individual streams than for global patterns, because of the placement of rests. Periods of 2 were only selected on nine occasions in Experiment 1B.

The fact that non-musicians took longer to respond than musicians in Experiment 1B suggests that their temporal experience of the music may be quite different from listeners with musical training. The ability to maintain a steady pulse may also be more difficult for non-musicians, due to the metric ambiguity generated by the patterns in this music. Independent of subject group, the number of times subjects deviated more than half a (semiquaver) beat from the selected template was greater for the set of low patterns than the set of high patterns. This finding does not appear to be a result of the ambiguity of the patterns, because the low stream patterns demonstrated less variety in responses. The high stream patterns, on the other hand, demonstrated a greater range of period and phase responses. Rather, the results could be attributed to the fact that the low patterns have fewer notes matching an isochronous template (cardinality = 5), in comparison with the high patterns which has a greater cardinality (cardinality = 7). There was no marked difference between musicians and non-musicians in terms of deviations from the beat, which also suggests that the complexity of the sequence did not influence the results.

Table 5-14 summarises the most commonly selected pulse trains for global patterns and individual (registral) streams where tempo = 139 ms.

Table 5-14 Most salient pulse sensations for global patterns and individual streams

The high pattern in $T_{0,11}$ had an equal number of subjects select pulse trains 6-2, 4-4, 6-3, and 6-5.

	$T_{0,0}$	$T_{0,11}$	$T_{0,10}$	$T_{0,9}$	$T_{0,8}$	$T_{0,7}$	$T_{0,6}$
global patterns	6-1	6-1	6-1	3-1	6-3	6-1	6-1
high stream	4-1	6-2; 4-4; 6-3; 6-5	6-3	3-3	4-1	12-3	6-3
low stream	6-1	6-6	6-1	3-1	6-3	6-1	6-1

With the exception of $T_{0,11}$, the most frequently selected pulse trains for the low stream match those of the global patterns in Experiment 1A. By contrast, the most salient pulse sensations generated by the high patterns are different to those of global patterns in every region. Similarly, the most salient pulse sensations for high and low patterns differ in each region. Bregman (1990) suggests that when stream segregation occurs, temporal relations between streams are lost, although this loss may not be total. The summary of results in Table 5-15 suggests that listeners derive their pulse sensations from notes of the low stream. The results of Experiment 1A, however, suggest that on many occasions, subjects' responses matched the results for the high stream patterns. For example, in $T_{0,0}$, five subjects chose the pulse-train 4-1, matching the most salient pulse sensation for the corresponding high pattern. Similarly, in $T_{0,0}$, six subjects chose the pulse train 4-1, matching the most salient pulse sensation for the high pattern in the same region.

Summary

Experiment 1A tested listeners' perception of pulse in Reich's *Piano Phase.* The results suggested that pulse perception in this music is highly ambiguous. Despite this ambiguity, the results of the experiment concurred with several aspects of Parncutt's (1994) model of pulse perception. That is, pulses tend to gravitate toward moderate tempo, and listeners' responses generally reflect a process by which sound onsets are mapped against the elements of an isochronous template.

In order to demonstrate that the variety of pulse sensations evoked in Experiment 1A were influenced by the rhythmic character of individual streams, Experiment 1B calculated the most salient pulse sensations for high and low resulting patterns. The results demonstrated that listeners have a tendency to derive their pulse sensations from notes of the low stream. The results also demonstrated however, that on many occasions, subjects' responses matched the results for the high stream patterns.

In summary, the results suggest that listeners' experience of pulse is dependent, to a large extent, on which of the resulting patterns are held in awareness. As suggested in the introduction to this chapter, the sudden perceptual shifts, which are experienced by listeners of Reich's music, can be explained by the process of metric reorientation, which occurs when listeners switch their attention (consciously or not) between different sub-patterns. The ambiguity of the principal pattern ($T_{0,0}$), which can be heard in groups of four or six, ensures that the patterns generated by the phase-shifting process will inherit a similar degree of ambiguity.

Chapter 6

Rating the Salience of Resulting Patterns in *Piano Phase*

Introduction

This chapter reports two experiments which were designed to measure the salience of resulting patterns in Reich's *Piano Phase*. The experiments tested both musicians and non-musicians, in order to investigate the extent to which musical experience contributes to listeners' ability to segregate patterns from the musical texture. The results obtained from the experiments reported in this chapter are used to examine the relationship between objective and subjective aspects of musical time. For example, the experiments test Cohn's (1992) argument, discussed in Chapter 4, that registral beat-class sets provide evidence of linearity in Reich's phase-shifting works, and that their design will have a direct impact on the listener's temporal experience. I argue that the following conditions would have to be true to satisfy Cohn's argument:

1. listeners must follow either the high patterns, or the low patterns throughout the music, and not switch their attention between registral beat class sets. By participating in figure/ground reversal, any detection of the linear progression formed by registral sets would be interrupted;
2. the linear progressions formed by each of the registral beat class sets would have to be salient, despite the presence of simultaneous *resultant patterns* which emerge through instrumental doubling (keeping in mind that these patterns have the capacity to form registral bc sets of their own); and
3. listeners would have to hear the registral sets as the most prominent sets, and their salience would have to be relatively consistent throughout prolongation regions.

In Chapter 4, I proposed that, according to stream segregation theory, the intervallic structure of the interlocking patterns in Reich's phase shifting works do not form compulsory registral streams. Rather, percepts derived from these patterns are relatively flexible. I argued that the unbiased 'inter-text' between high and low patterns creates a preference for figure/ground reversal (or figure/figure reversal), where the listener switches attention between available patterns. The only way this would not happen is if the listener purposefully kept either the high or low set in awareness for the duration of the piece. However, maintaining such a path throughout an entire work is unlikely, due to the intervallic structure of principle patterns, and the sudden perceptual shifts which occur naturally through the process. These factors weaken the probability of the condition in point 1.

In Chapter 4, I examined the nature of patterns formed by instrumental doubling in *Phase Patterns* and *Violin Phase*. The participation of these patterns in the overall texture, specifically, their contribution to the nature of temporality, has not been considered in previous analyses. I argued, according to the rules of stream segregation, that their presence has a tendency to freeze the play of the musical system. That is, the resulting percepts formed by the interlocking structure of principle patterns fall into the background, and the patterns pointed out by instrumental doubling are heard on the surface of the overall texture. In this sense, such patterns can be compared with the 'vocal nuclear themes' present in examples of East and Central African music, which are played over the top of interlocking patterns. Therefore, I argue that the capacity of new resultant patterns to form unique beat class sets, and the prominence of these patterns in the overall texture (ensured by instrumental doubling and louder dynamic specifications), reduces the possibility that a listener will be attuned to the linear progressions identified by Cohn. These factors rule out the condition in point 2.

The experiments reported in this chapter are designed to argue point 3 above: that is, that the salience of beat-class sets is consistent throughout the prolongation regions of Reich's music. This evidence is necessary in order to accurately assess the nature of temporality in Reich's early works. The results of the following experiments, in combination with the experiments presented in Chapter 5, are used to develop a contextual framework in which Reich's music may be placed (Chapter 7).

Experiment 2A: Rating the Salience of Resulting Patterns

Theoretical Background

The review of literature in Chapter 3 revealed that only a small number of studies have attempted to explore the role of stream segregation in authentic musical examples drawn from the repertoire. Bregman and Wright (1987) attempted to control the perception of dissonance in contrapuntal patterns using stream segregation principles. Huron (1989a) considered the role of auditory stream segregation in the music of J.S.Bach, specifically, whether or not Bach's polyphonic works provide evidence that he endeavoured to minimise perceptual confusion. Similarly, Huron and Fantini (1989) and Huron (1991) analysed a set of Bach fugues to demonstrate that Bach's arrangement of inner-voice entries reflect a concern for enhancing voice distinction. The results of these studies are based on score analysis, rather than through actually testing listeners' perception of the clarity of contrapuntal patterns or inner-voice entries through experimentation. Wegner (1993), on the other hand, investigated the cognitive strategies that form the perception of Kiganda xylophone music by testing the "intercultural validity of Gestalt laws by disenabling them in modified standard performances" (p. 202). I advocate Wegner's approach, as it provides a meaningful understanding of the experience of the music studied. For example, Wegner not only considers the 'inherent patterns' generated by interlocking structures, but also their relationship to other features of the music, such as the vocal nuclear theme. I argued in Chapter 3 that with the exception of Wegner (1993), other studies which have considered the role of segregation in comparatively linear forms of music, do not necessarily reveal anything about the music which is not already known intuitively by musicians and composers.

By testing the salience of resulting patterns in Reich's music, it is possible to explore levels of ambiguity in the perception of patterns. I argue that the salience of patterns has a significant bearing on the resulting temporal experience. In the introduction to Chapter 3, I suggested that several factors must be taken into account when applying the rules of segregation (which were developed using simple auditory sequences in a controlled environment) to musical examples from the repertoire. These factors, which are taken into account in the analysis, include culture, musical background, stylistic boundaries, and performance context. The majority of studies which tested the segregation of simple auditory sequences (for example, Anstis & Saida, 1985; Bregman & Campbell, 1971; Bregman & Pinker, 1978; Bregman & Rudnicky, 1975; van Noorden, 1975) were concerned with investigating primitive processes of organisation. That is, they were not concerned with how grouping processes might be influenced by individual differences in subjects. Individual differences are particularly important when dealing with musical examples, because musical schemas are assumed to play an important role in the perception of musical patterns. Dowling's (1973) study is an example of how researchers have attempted to explore the difference between primitive and schema-based segregation. He investigated the effects of pre-familiarising subjects with arbitrary sequences of tones when mixed with other sounds. Familiar sequences were found to be more easily detected than unfamiliar ones. In order to determine whether or not musical experience has a significant bearing on listeners' ability to segregate patterns in Reich's phase-shifting music, I tested both musicians and non-musicians in Experiments 2A and 2B.

In Chapter 3, I highlighted the suitability of repetitive sequences (and consequently, repetitive music) for testing the boundaries of stream segregation. For example, repetition allows an investigation of the temporal order of events in a relatively unchanging context. The complexity of Reich's music, in comparison with simple two or three tone sequences, requires a more considered approach to experimentation. In the evaluation of measures, presented in Chapter 3, I suggested that the relative complexity of Reich's music made the majority of existing measures unsuitable. These included methods such as adjusting a property of the sequence, drawing or writing down what you hear, measuring the proportion of time integrated and segregated, and indicating how many streams are present. In addition, I argued that these measures were generally incompatible with the experience of music listening, and that results obtained using these measures are in danger of being misconstrued. By comparison, I argued that measures such as recognising patterns, or detecting rhythm changes, are relatively less foreign to the experience of music listening.

Research has shown that the ability to recognise patterns is significantly influenced by the streaming process (for example Bregman & Rudnicky 1975). If a pattern is formed from notes belonging to a single stream, it is recognised easily. On the other hand, if a pattern is formed from notes belonging to two or more different streams, recognition becomes increasingly difficult. For example, Tougas and Bregman (1985a: Exp.1, Exp.2) presented a target pattern in isolation, and then presented it as part of a more complex pattern. The target patterns contained a sequence of tones that "would be isolated if the listener were organizing the test sequence in a particular way" (p. 57). At the end of each trial, listeners were asked to rate the clarity of isolation of the target pattern on a rating scale. Bregman (1990) supports the pattern recognition method, stating that the task of isolating one pattern from another represents the basic nature of the scene analysis process. Most importantly, this method can be used to determine "which of several ways of hearing an ambiguous stimulus is stronger" (p. 57). The methodology implemented in Experiments 1A and 1B is adapted from the Tougas and Bregman study (1985a), which investigated the salience of within and across stream patterns.

It is assumed that any component that causes distracter sounds (introduced in the comparison sequence) to be integrated into a separate stream, will make the target pattern easier to detect. This is the case regardless of whether or not the target pattern is a familiar sequence, or an unfamiliar sequence that listeners have just been played as a target pattern, that is being held in the listeners immediate memory (Bregman, 1990). Therefore, if the salience of a pattern is low, it can be argued that stream segregation does not organise the patterns clearly into registral groups. That is, alternative configurations may be more salient in some regions.

Aim

Experiment 2A was designed to explore the clarity of resulting patterns in Reich's *Piano Phase*. Specifically, it was designed to test for:

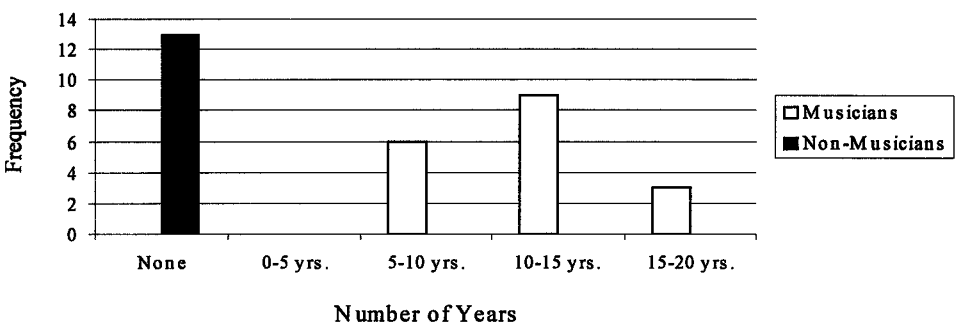
1. differences in the salience of the seven high patterns;
2. differences in the salience of the seven low patterns;
3. differences in the salience of high patterns and low patterns within each region;
4. the effect of tempo on the salience of patterns; and
5. the difference in ability between musicians and non-musicians to clearly isolate high and low resulting patterns.

Methodology

Subjects

Thirty-one subjects (21 females and 10 males) participated in Experiment 2A.[17] Musical and non-musical groups were established to test the influence of musical experience on listeners ability to isolate resulting patterns. Subject groups were determined according to how many years the participant had studied a musical instrument. The subject sample consisted of 18 musicians and 13 non-musicians. The musical experience of subjects ranged from 0-20 years. Figure 6-1 shows the distribution of subjects who had learnt at least one instrument, and the number of participants who had never studied a musical instrument.

Figure 6-1 Number of years playing a musical instrument



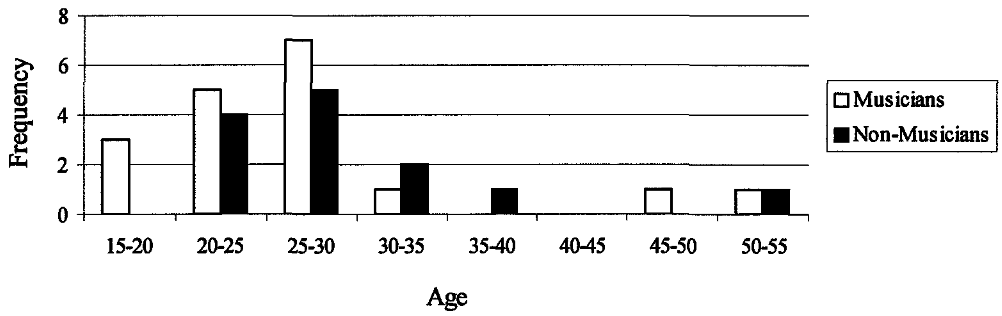
As indicated by Figure 6-1, the 13 non-musicians had never learnt a musical instrument, while the majority of subjects in the musicians group had studied a musical instrument for between ten and fifteen years. Three musicians had between fifteen and twenty years of playing experience. Figure 6-1 indicates a clear division between musical and non-musical groups, with no subjects falling into the second category (0-5 years). The distinction between musical and non-musical groups was crucial, so that the role of musical experience could be assessed in terms of subjects ability to segregate patterns from Reich's music. Of the 31 subjects, 11 were enrolled

[17] The number of subjects tested in this experiment was just over double the number tested in the Tougas & Bregman study (1985), who tested the salience of sub-patterns according to their pitch and trajectory characteristics (see review in Chapter 3).

full time in undergraduate courses in Music or Music Education at the University of New South Wales.

The youngest participant was 18 years of age, and the oldest was 54. The mean age of participants was 27.6 years. Figure 6-2 shows the distribution of subjects according to age. As indicated, the majority of subjects were between 25-30 years of age. The number of years spent playing an instrument was relatively evenly distributed across males and females.

Figure 6-2 Distribution of participants according to age



Questionnaire

A questionnaire was completed by all participants prior to the experiment. The questions were designed to collect information specific to the musical background and experience of participants (Appendix D). Questions were organised according to the following categories:

A: Musical Background and Experience

B: Attitude Towards Music

C: Musical Ability

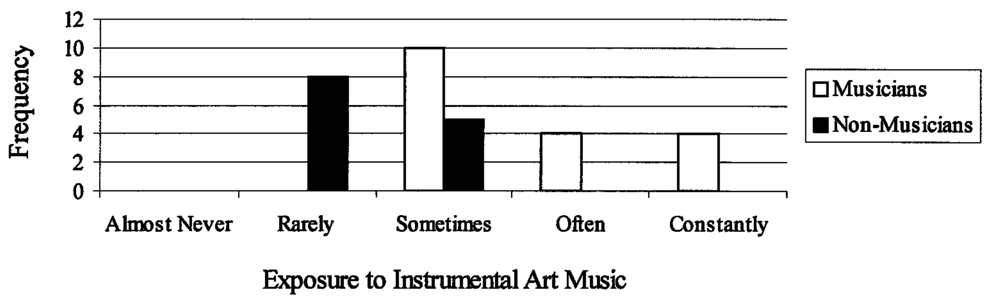
D: Post-Experiment Questionnaire

Section A collected details of any formal musical training in performance or theory, and asked subjects to indicate, using a five-point rating scale, the amount of time they spent listening to a range of different musical styles (1. Almost never; 2. Rarely; 3.

Sometimes; 4. Often; 5. Constantly). Of particular interest, was the amount of time participants spent listening to instrumental Western art music, and contemporary art music. The distribution of subjects, according to the amount of time spent listening to these styles, is indicated in Figure 6-3.

Figure 6-3 Exposure to Instrumental Art Music and Contemporary Art Music

a.



b.

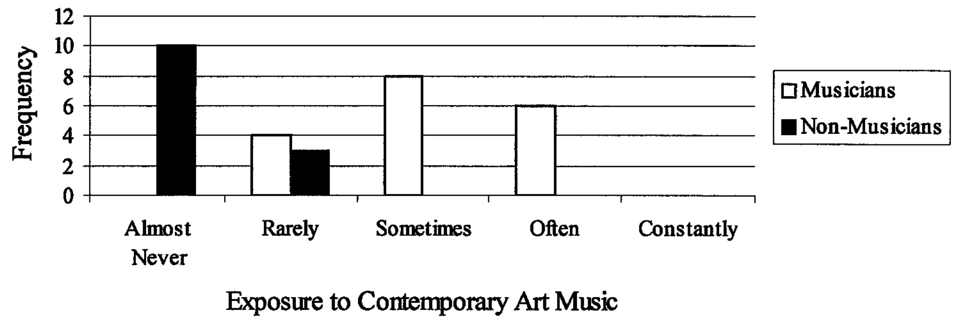


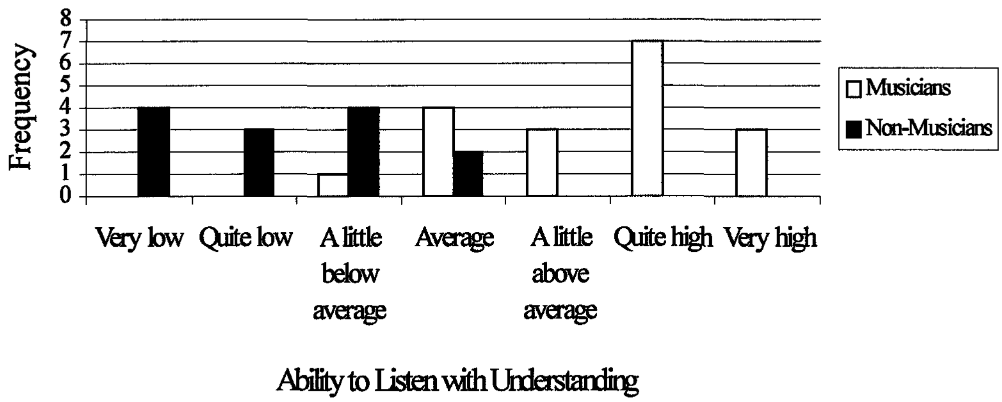
Figure 6-3a indicates that the majority of subjects listened to instrumental art music at least sometimes. Subjects who listened to instrumental music rarely were all non-musicians. Eight subjects in the musicians group had a high level of exposure to instrumental music, indicating that they listened often, or constantly. As indicated in Figure 6-3b, no subjects indicated that they listened to contemporary art music constantly. All subjects who indicated that they almost never listened to contemporary music were non-musicians, that is, they had never learnt a musical instrument. The level of exposure to contemporary art music for subjects in the musicians group was distributed between 'Rarely', 'Sometimes' and 'Often'.

Importantly, Figure 6-3b indicates that 14 of the 18 musicians listened to contemporary music at least sometimes.

Section B of the questionnaire collected information regarding subjects' attitude toward music. More specifically, it asked participants to rate the extent to which they enjoyed listening to different types of music. In section C of the questionnaire, subjects were asked to rate their ability to play a musical instrument, to read musical notation, to compose and improvise music, to sing in tune, and to keep in time. Four questions in this section of the survey asked subjects to rate their ability to listen with understanding to various types of music. Subjects were informed that listening "with understanding" meant recognising elements in music such as harmonic progressions, motivic development, structural characteristics, and other formal features.

This information was considered to be particularly important when assessing the role of musical schemas in the perceptual organisation of Reich's music. Based on previous research, it is expected that participants with a greater ability to listen 'with understanding' to a range of musical styles have developed stronger schemas for music than those with little understanding of the structural characteristics of music. This information is used to assess the role of musical training and musical knowledge on listeners ability to segregate patterns in Reich's music. Figure 6-4 shows the distribution of responses for musicians and non-musicians when asked to rate their ability to listen with understanding to a range of musical styles.

Figure 6-4 Ability to Listen with Understanding



Responses in Figure 6-4 show that, with the exception of one subject, people in the musicians group indicated a moderate to very high level of ability to listen with understanding to a range of musical styles. The majority of musicians indicated that their ability to listen with understanding was quite high. Three musicians indicated a very high level of understanding. By contrast, with the exception of two subjects, non-musicians rated a below average ability to listen with understanding to a range of musical styles. More than half the subjects in the non-musicians group indicated a 'Quite low' or 'Very low' ability.

The mean responses for all thirteen questions related to musical ability in section C of the questionnaire were calculated for each subject. Table 6-1 shows the mean scores for each item according to musicians and non-musicians. On the seven-point rating scale, the minimum mean score for musicians was 4.44 (item 12), and the maximum was 6.11 (item 7). By comparison, the minimum mean score for non-musicians was 1.31 (item 3), and the maximum was 3.15 (item 10).

Table 6-1 Mean Scores for Items in Section C: Musicians and Non-Musicians

Item	Musicians		Non-musicians	
	Mean	SD	Mean	SD
1	5.72	0.67	1.92	1.03
2	5.50	1.50	1.62	1.04
3	4.83	0.86	1.31	0.63
4	5.16	0.98	1.54	0.66
5	5.72	1.36	2.77	1.48
6	5.28	1.27	2.76	1.48
7	6.11	0.75	2.92	1.32
8	5.33	0.91	2.62	1.26
9	5.50	1.10	2.31	1.11
10	6.00	0.91	3.15	1.14
11	5.28	1.13	2.38	1.33
12	4.44	0.98	2.07	1.19
13	5.88	0.47	2.53	1.13

A multiple comparisons Scheffé test revealed significant differences ($p<.05$) between musicians and non-musicians for each of the 13 items on this section of the questionnaire.

Subjects filled out Section D of the questionnaire at the completion of the experiment, which was designed to determine if any problems were experienced during the course of the experiment. On a seven-point rating scale, subjects were asked to rate the difficulty of the task.

Figure 6-5 Distribution of subjects according to the difficulty of the task

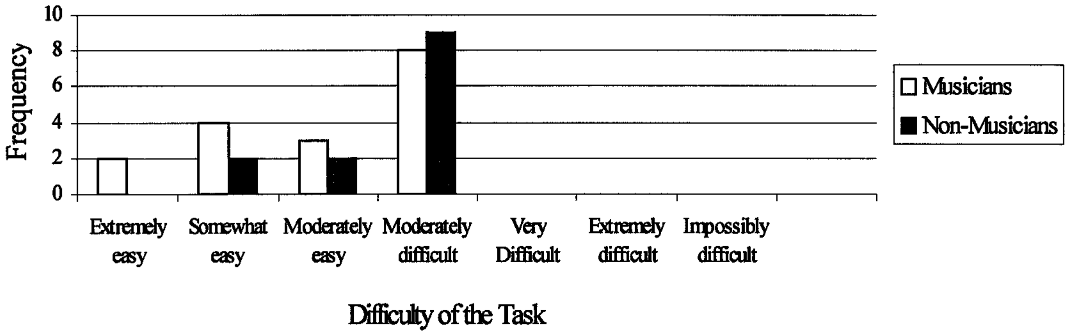


Figure 6-5 indicates that the majority of subjects found the task moderately difficult. No subjects rated the task 'Very difficult' or above. These results were considered in association with a further question, which asked subjects if they ever changed their mind (and consequently changed their responses) when using the rating scale.

Figure 6-6 Frequency with which subjects changed their responses on the rating scale

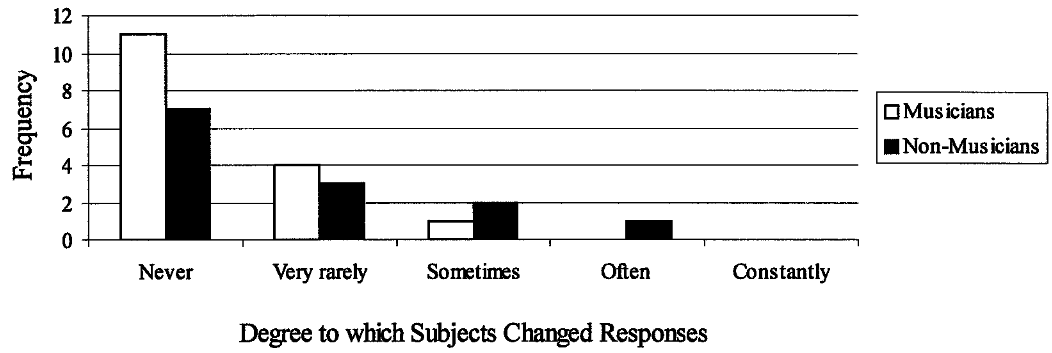


Figure 6-6 indicates that more than 50% of subjects never changed their rating scale responses. The remaining subjects only changed their responses very rarely or sometimes. Only one subject altered her responses often. These results provide evidence that the rating scale was a suitable device for indicating different degrees of clarity. That is, if subjects changed their minds constantly throughout the experiment, the suggestion would be that subjects were not confident with their selection, and that the calibration of the rating scale made it difficult to distinguish levels of clarity. Overall, the results in Figure 6-6 suggest a very low level of deliberation.

The majority of subjects indicated that they had never heard the musical excerpts presented in the experiment, or that they were not sure if they had heard them before. Four subjects reported that they had heard the musical examples once or twice before. The musical sequences presented in the experiment were mostly unfamiliar to subjects.

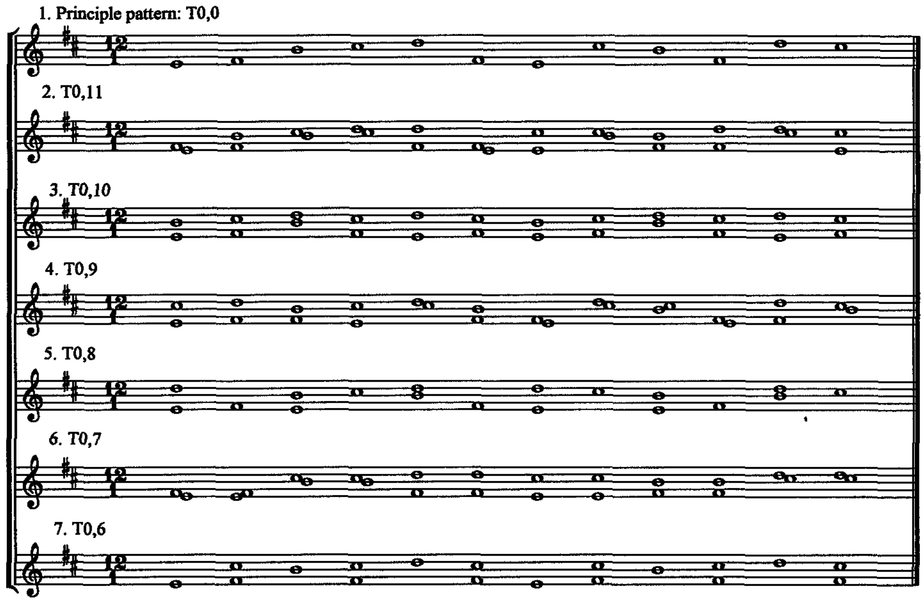
Several colleagues from the School of Music and Music Education at the University of New South Wales, were consulted in order to ascertain whether or not the questions asked in the questionnaire were appropriate for distinguishing musical and non-musical groups. Each of the people consulted agreed that the set of questions formed an appropriate measure.

Stimuli

The stimulus patterns used in this experiment were excerpts from section A of Steve Reich's *Piano Phase*. Sequences included the principal pattern ($T_{0,0}$), and the first six prolongation regions {$T_{0,11}$; $T_{0,10}$; $T_{0,9}$; $T_{0,8}$; $T_{0,7}$ and $T_{0,6}$}. The patterns presented in the experiment were divided into target patterns and comparison patterns. The seven comparison patterns matched the principle pattern and the first 6 prolongation regions exactly (see Figure 6-7).

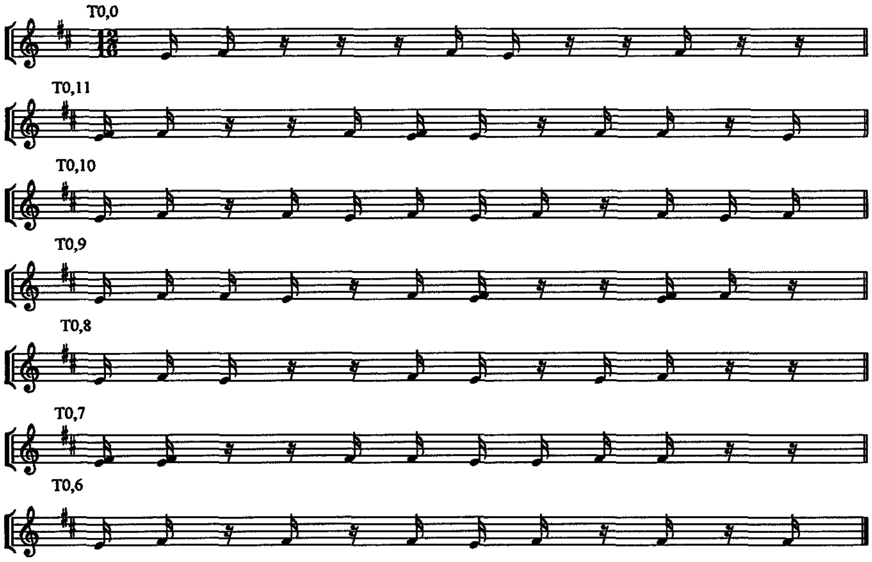
Figure 6-7 Target and Comparison Patterns Used in the Experiment

Comparison patterns



High target patterns

Low target patterns



As shown above, the target patterns represent divisions of each phase into two sub-patterns: notes of the high stream (B, C#, and D) and notes of the low stream (E and F#). Therefore, each comparison pattern was associated with two target patterns. It is assumed that although these sequences represent probable resulting patterns (beat-class sets), their salience in each region will be significantly affected by elements of pattern structure such as contour, tempo, rhythmic regularity and metric stability. Similarly, the allegiance of the "B" to one stream or another is expected to vary according to its position in the sequence.

Phases 7 to 11 ($T_{0,5}$ - $T_{0,1}$) of *Piano Phase* were not tested, because they contain the same structure as the first six phases (in a retrograde design). The only difference is that they begin on a different beat of the twelve beat cycle. This is not considered to have any effect on the perception of the resulting patterns because of the level of repetition which tends to cancel out the significance of starting and ending points (Bregman, 1990). In the experiment, each pattern (shown in Figure 6-7) was cycled four times, creating a continuous pattern. The seven different target and comparison pairs were crossed with three different presentation rates: 139 ms (crotchet = 108, or dotted crotchet = 72); 189 ms; and 239 ms. These values indicate the distance between note onsets. The duration of tones was set at 50 ms less than the distance between note onsets. That is, durations were 89 ms, 139 ms and 189 ms depending on the tempo of the sequence.

Programming and Materials

As with Experiments 1A and 1B, the experiments reported in this chapter were designed by the researcher to be operational on a Power Macintosh computer (6300). Several aspects of the program, such as the subject's interface and the order of trials are provided in Appendices E, F, G and H. Programs were developed specifically for the experiment using Max 3.5, an interactive music software package. The programs created for the experiment were designed to introduce the participant to the experiment, coordinate the timing of musical sequences, control the order of trials, generate the subject interface, and record and organise data. When subjects demonstrated their familiarity with the requirements of the experiment, they were instructed to click a button using the mouse to begin the first trial. Comparison patterns were programmed to follow target patterns after an interval of 1.6 seconds. At the end of each comparison pattern, a rating scale replaced the instructions screen. Once again, subjects clicked on the appropriate buttons to register the extent to which target patterns could be isolated in the comparison patterns. Responses were simultaneously saved into a separate file, which indicated the name of the trial and the corresponding response. The instructions for the experiment appeared on the screen at the beginning of every trial for reference.

Comparison patterns were created by synchronising the principle pattern with its relevant transposition. That is, duplicates of the principle pattern were programmed so that they resembled the order of events played by the second piano in *Piano Phase*. In each trial, the duplicates triggered the simultaneous onset of the principle pattern.

As in Experiments 1A and 1B, all subjects were tested on the same computer, and all were conducted in the "Electronic Music Studio", a facility provided by the School of Music and Music Education at the University of New South Wales. In order to ensure that the experimental program ran fluently from beginning to end, two colleagues from the School of Music and Music Education, including one doctoral candidate and the Head of the School of Music Education, completed the experiment prior to the period of testing. No inconsistencies were detected by either participant.

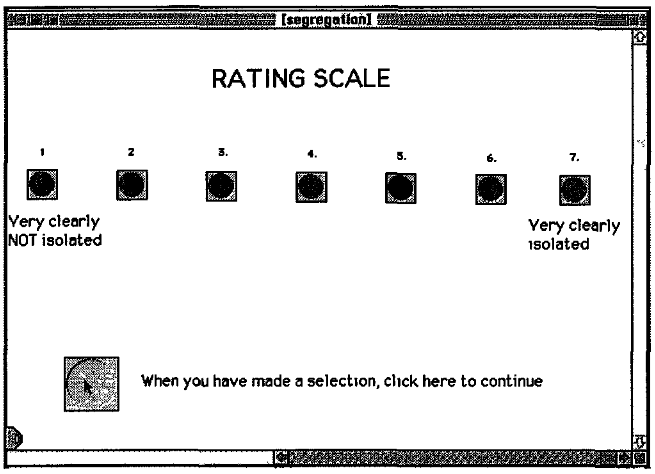
Procedure

Participants were tested one at a time while the experimenter sat outside the studio, and was available for help if necessary. Each participant was allocated a one hour time slot to complete the questionnaire, a short practice session, and the main experiment. The initial screen of the experiment was explained to the participant by the researcher, and they were asked to follow the instructions on the computer screen. The practice session consisted of three demonstration trials, and three practice trials, to allow the subject to become familiar with the task, and to promote consistent use of the rating scale. When the practice session was complete, the subject was asked to click a button on the display to begin trial number one.

Following Tougas and Bregman's method (1985a), the subjects were informed that the experiment was designed to investigate the way people hear tones when they are surrounded by other tones. The subjects were told that on each trial, they would be presented with a pair of sequences, that is, a 'target' sequence followed by a 'comparison' sequence. They were told that the comparison sequence was composed of the target sequence mixed together with other surrounding tones.

In each trial, the subjects heard four continuous repetitions of the target pattern, a 1.6 second silence, then four repetitions of the comparison pattern. The ability of a coherent auditory stream to be heard as an entity that is perceptually isolated from the surrounding sounds was used as an index of stream formation. At the end of each trial, subjects were asked to rate how clearly isolated the target pattern was, when heard as part of the comparison sequence. Responses were made on a seven-point rating scale. The endpoint (1) of the rating scale was labelled 'very clearly not isolated', meaning that the standard sequence could not be heard at all within the comparison sequence. The other endpoint (7) was labelled 'very clearly isolated' (see Figure 6-8).

Figure 6-8 Rating Scale Used in Experiment 2A



Subjects were told that if they were to rate the target pattern 'very clearly isolated', they should be able to isolate the pattern without *any* effort. The subjects understood that the target sequence was always present in the comparison sequence, but that it would not always be easy to isolate.

The target and comparison pairs were presented to subjects in one of three orders. The order of trials were constructed to eliminate the possibility of the same target pattern being presented in consecutive trials to minimise learning effects. The order was determined randomly when the program was initiated. The order selected for each subject was recorded. A visual inspection of data revealed no relationship between subjects' rating responses and the order of trials.

Design

The three variables in Experiment 2B were:

1. the seven types of stimulus patterns (comparisons);
2. the two types of target patterns (high and low resulting patterns); and
3. the three different presentation rates: 139 ms, 189 ms, and 239 ms.

The total number of trials in the experiment was 42 (7x2x3).

The results for Experiment 2A are discussed in conjunction with the results of Experiment 2B, the methodology of which is outlined below. A comparison of results is made between the two experiments, which addresses the role of rhythmic regularity and predictability in the formation of resulting patterns.

Experiment 2B: Rating the Salience of Beat-Class Sets

Aim

The aim of Experiment 2B was to assess the influence of rhythmic regularity and predictability on subjects ability to isolate resulting patterns, by comparing the results with Experiment 2A.

Experiment 2B tested the salience of beat-class sets in the same seven regions of *Piano Phase*. By examining the rhythmic component of patterns separately from the melody, it is possible to assess the role of rhythmic regularity in the formation of streams. That is, if the order of mean rating scale responses (from least to most clear) is reflected across experiments, we can assume that rhythm plays a significant role in subjects' ability to isolate resulting patterns.

Methodology

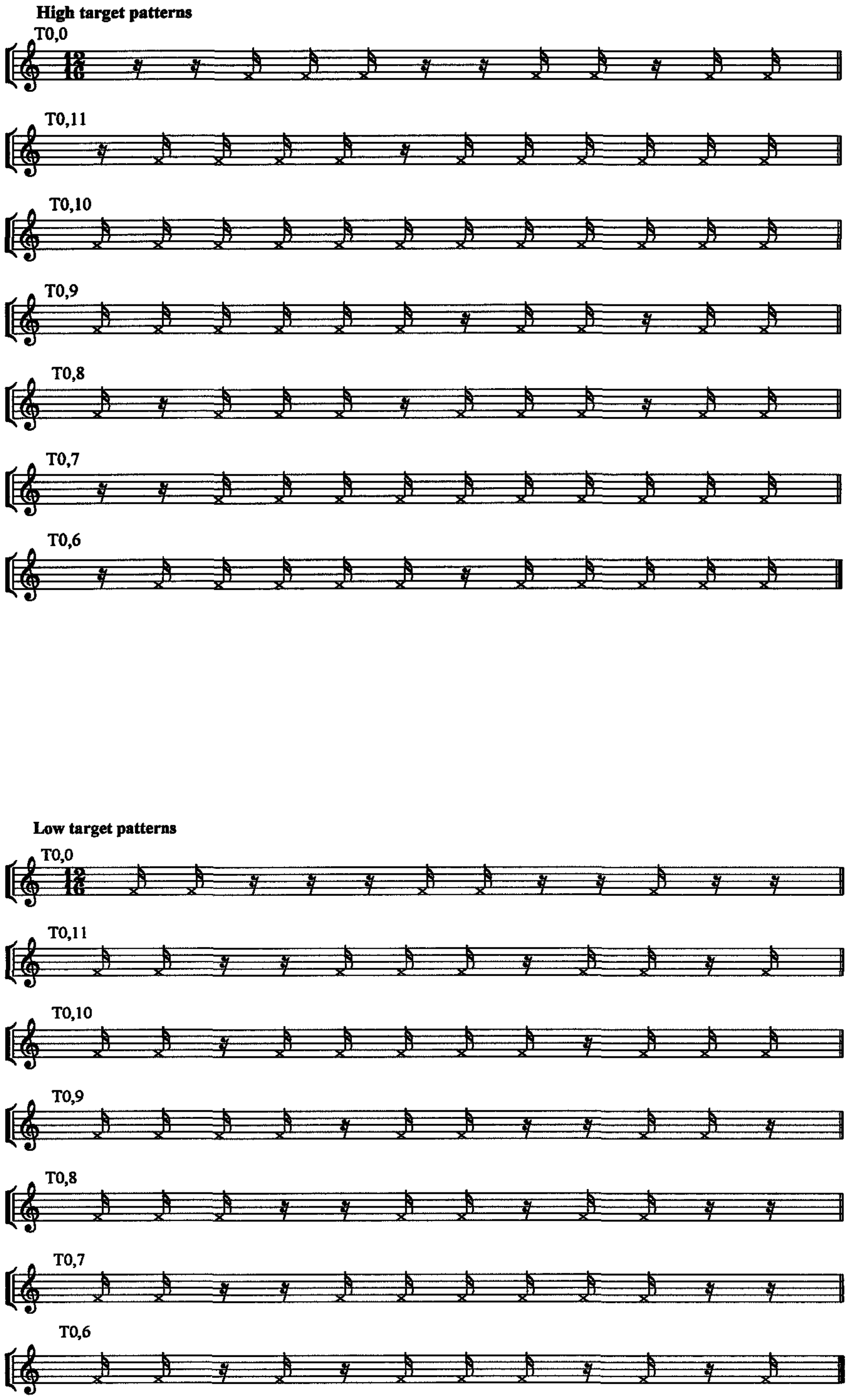
Subjects

All of the subjects who participated in Experiment 2A were tested in Experiment 2B. The experiments were conducted approximately three weeks apart to minimise learning effects.

Stimuli

Once again, sequences consisted of target and comparison patterns. The comparison patterns were identical to those presented in Experiment 2A, that is, they consisted of the principal pattern (T0,0) and the first six prolongation regions of *Piano Phase* using a piano sound. The difference between Experiments 2A and 2B, was that target patterns in Experiment 2B were presented on a click track. That is, they consisted of the rhythmic sequence associated with the high and low beat-class sets only (see Figure 6-9).

Figure 6-9 High and Low Rhythmic Target Patterns



Rhythmic patterns were created using Max 3.5, and presented using a 'click' sound from a Kurtzweil 2000. The volume of clicks was consistent for each subject, who heard the sequences through high quality headphones.

Programming

Information regarding the order of trials, the subject interface, and the programs developed for the experiment are provided in Appendices E, F and G. Once again, the software Max 3.5 was used to write the programs for the experiment. The program was developed to coordinate the timing of musical sequences, the order of trials, the subject interface, and the compilation of data. There was a 1.6 second silence between the end of the target pattern and the beginning of the comparison pattern. At the end of each comparison pattern, a rating scale replaced the instructions screen. Responses were saved into a separate file, indicating the name of the trial and the corresponding response.

Procedure

As before, the subjects were informed that the experiment was designed to investigate the way people hear tones when they are surrounded by other tones. Participants were informed that on each trial, they would be presented with a 'target' sequence followed by a 'comparison' sequence. They were told that the target sequence consisted of a rhythmic pattern presented on a click track, and that they would be asked to rate how clearly the target rhythm pattern could be isolated in the comparison. They were informed that the rhythmic sequence was present in the comparison, but that it would not always be easy to isolate.

Once again, target and comparison patterns were cycled four times. At the end of each trial, subjects were asked to rate (on a 7-point scale) the 'clarity of isolation' of the rhythmic target sequence when heard as part of the comparison sequence. The ability of subjects to isolate a rhythmic target pattern was used as a measure of stream formation.

Design

The three variables in Experiment 2B were:

1. the seven types of stimulus patterns (comparisons);
2. the two types rhythmic target patterns (presented on a click track); and
3. the three different presentation rates: 139 ms, 189 ms, and 239 ms.

Again, the total number of trials in the experiment was 42 (7x2x3).

Results and Discussion

In contrast to Chapter 5, the results and discussion of Experiments 2A and 2B are presented together in this section. This decision was based on the quantity of data, which has been divided according to a number of themes, and the fact that the significance of the numerical data is difficult to follow without the use of notated musical examples.

The rating responses of the 31 subjects were averaged for each trial, creating a mean score between one and seven. These scores were taken as an index of stream segregation. The presentation and discussion of results for Experiments 2A and 2B is divided into five sections. In the first section, I consider the relationship between mean scores and the structural characteristics of each pattern. For example, I consider whether or not the clarity of resulting patterns is influenced by rhythmic regularity. According to Jones' rhythmic theory of attention (discussed in Chapters 3 and 4), regular patterns provide better prediction, and should therefore form more coherent streams. That is, when the temporal position of future sounds can be anticipated in a musical sequence, they are more likely to be "caught in the net of attention" (Bregman, 1990, p. 412).

The second section of the results considers the differences between the clarity of high and low patterns within each region. In accord with Tougas and Bregman (1985), target patterns contain a sequence of tones that would be heard clearly if the listener was ordering the pattern in a specific way. The results reported in this section are used to determine which of two ways of hearing an ambiguous pattern is dominant. In the third section of the results I discuss the effect of tempo on the clarity of resulting patterns. The findings are considered in relation to the principle of stream segregation (discussed in Chapter 3) which states that as the tempo of a sequence increases, stream segregation is strengthened.

In section four, subjects' ability to isolate sub-patterns is assessed in terms of musical experience. That is, mean scores are compared for musicians and non-musicians. Although the results for Experiments 2A and 2B are reported in each of the previous sections, the final section of the discussion compares them directly. For example, if the mean scores for rhythmic target patterns (Experiment 2B) reflect the mean scores for melodic target patterns (Experiment 2A) in each region, it is assumed that rhythm plays a significant role in listeners' ability to isolate resulting patterns (in accord with Jones, 1981). Conversely, if there is little or no similarity, it is assumed that the coherence of resulting patterns cannot be attributed to rhythmic attention alone (in accord with Bregman, 1990).

Due to the fact that all subjects responded to all conditions of the experiment, a repeated measures analysis of variance was conducted for the scores of both Experiments 2A and 2B.[18] The analysis was used to determine whether there was a significant difference between the clarity of high and low resulting patterns. The analysis was also used to investigate whether there was a significant difference between musicians and non-musicians, in terms of their ability to isolate target patterns.[19]

Mean scores for clarity of isolation

The results presented in this section report mean scores for high and low target patterns in Experiments 2A and 2B. The results are considered in terms of how the texture of each pattern contributes to the clarity of the two-voice texture, or conversely, how texture contributes to the coherence of simultaneously occurring sounds. In addition, it considers whether or not rhythmic regularity enhances the clarity of resulting patterns.

Epstein (1986) acknowledges that the character and distinction of the two-voice texture varies among patterns in *Piano Phase*. For example, he suggests that the polyphonic nature of T0,8 (shown in Figure 6-10) contributes to the clear division of registral patterns. In region T0,10, the upper voice is supported by the lower voice homophonically. This configuration significantly obscures the contour of the original (principal) pattern. Epstein states that the registral patterns in T0,7, T0,11 and T0,6 do

[18] SPSS was used for all analyses reported in this chapter.
[19] The type of analysis used in Experiments 2A and 2B resembles Tougas and Bregman (1985), who tested the salience of sub-patterns according to their pitch and trajectory characteristics (see Chapter 3).

not separate to the same degree. In these regions, the contour of the principal pattern is less obscured (see Figure 6-10).

Figure 6-10 Differences in the clarity of the two-voice texture

Direction of note stems indicate the clarity of the two-voice texture according to Epstein (1986)

Table 6-2 shows the mean scores (from least clear to most clear), standard deviation and range, for high and low patterns in Experiment 2A (IOI=139ms). In accord with Epstein, subjects found the high pattern T0,10 relatively easy to isolate (5.50). The ability of subjects to isolate the pattern may also be enhanced by the predictability of the rhythmic pattern, which is isochronous in this region. The low pattern in T0,10, however, generated the lowest average response (2.87). This suggests that the division of the two-voice texture may be characterised by the margin between the clarity of the two voices.

Table 6-2 Descriptive statistics for high and low patterns in Experiment 2A

(a) High patterns

Region	Mean	SD	Min.	Max.
T0,9	3.87	1.53	1	7
T0,0	4.63	1.96	1	7
T0,6	4.73	1.82	1	7
T0,8	4.77	1.43	2	7
T0,11	4.80	1.42	2	7
T0,10	5.50	1.46	2	7
T0,7	5.70	1.37	3	7

(b) Low patterns

Region	Mean	SD	Min.	Max.
T0,10	2.87	1.38	1	6
T0,8	3.57	1.83	1	7
T0,11	3.63	1.65	1	7
T0,6	3.97	2.22	1	7
T0,7	4.10	1.92	1	7
T0,9	4.33	1.84	1	7
T0,0	4.63	2.01	1	7

The results show that the high pattern in $T_{0,8}$ was moderately easy for subjects to isolate relative to the other patterns. The low pattern in this region was less easy to isolate. These results contradict Epstein's claim that the two-voices separate easily in this region. Van Noorden's (1975) fission and segregation boundaries suggest that the B may be captured by the low stream (see Figure 6-11), making it difficult to isolate the melody comprising E and F# only.

Figure 6-11 Alternative configuration for the low stream pattern in T0,8

As mentioned above, Epstein (1986) suggested that registral patterns in T0,11, T0,7 and T0,6 were not easily separated. The high pattern in region T0,7, however, produced the highest average clarity of isolation (5.70). This finding supports Jones' rhythmic theory of attention, which states that regular patterns form more coherent streams. The results for Experiment 1B, reported in the previous chapter, showed that a large number of subjects selected periods of 12, that is, subjects tapped only once per cycle. The structure of the pattern, which consists of a series of repeated dyads, may contribute to listeners ability to build a strong rhythmic representation of the pattern. Rhythmic characteristics may also account for the clarity of patterns in T0,9 (see Figure 6-12).

Figure 6-12 Two-voice division of T0,9

As shown in Table 6-1, the high (syncopated) pattern in this region was the most difficult to isolate on average (3.87). The low pattern however, which is less rhythmically ambiguous, was relatively clear.[20]

[20] Experiment 1B, reported in Chapter 5, showed that the majority of subjects agreed on the same pulse train (3 - 1) for the low pattern in T0,9. This is contrasted with the results for the high stream in this region, which evoked both periods of 3 and 4.

A repeated measures analysis of variance revealed a significant main effect ($p<.05$) for pattern (refer to Figure 6-2). Paired comparisons for high target patterns revealed significant differences ($p<.05$) between the salience of T0,9 and every other pattern except T0,0. Other significant differences ($p<.05$) in pattern clarity occurred between the high patterns of T0,8 and T0,10; T0,0 and T0,7; T0,6 and T0,7; and T0,6 and T0,10. For low target patterns, there was a significant difference ($p<.05$) between T0,10 (the lowest scoring pattern) and every other region except T0,8. Other significant differences ($p<.05$) occurred between T0,8 and T0,0; T0,8 and T0,9; T0,11 and T0,0; and T0,11 and T0,9. Together, these results suggest that the difference between the salience of resulting patterns in each region should be considered when assessing the temporal nature of this music, for it is possible that the variation in the salience of beat-class sets demonstrated in these results reduces the strength of attack-point design as a force of perceived linearity.

Table 6-3 shows the average rating responses (in order from least isolated to most isolated) for the rhythmic target patterns presented in Experiment 2B. Once again, the rhythmic pattern derived from the high stream in T0,10 was one of the most salient patterns, while the low pattern in the same region was the most difficult to isolate.

Table 6-3 Average responses for high and low rhythmic patterns in Experiment 2B

(a) High patterns

Region	Mean	SD	Min.	Max.
T0,8	3.36	1.85	1	7
T0,0	3.68	1.77	1	7
T0,9	4.16	1.65	1	6
T0,11	4.64	1.55	2	7
T0,6	4.64	1.63	2	7
T0,10	5.64	1.66	1	7
T0,7	5.76	1.23	4	7

(b) Low patterns

Region	Mean	SD	Min.	Max.
T0,10	3.44	1.88	1	7
T0,11	3.56	1.64	1	7
T0,8	3.72	1.88	1	7
T0,6	3.92	1.75	1	7
T0,7	4.08	1.53	1	7
T0,0	4.28	2.35	1	7
T0,9	4.52	1.81	1	7

Subjects rated both the high and low patterns in region T0,8 as not clearly isolated (3.36 and 3.72 respectively). Although Epstein (1986) suggested that the polyphonic nature of T0,8 enhanced the separation of the two voice texture, registral beat-class sets were not heard as clearly isolated by subjects. The low beat-class set in T0,9, although not a high average response, was rated the highest of all the low patterns. Jones (1981) suggests that this result may be attributed to the rhythmic stability of the low pattern.

A repeated measures analysis of variance revealed a significant main effect ($p<.05$) for pattern. Paired comparisons revealed that the clarity of the high pattern in T0,8 was significantly different ($p<.05$) from the high patterns in T0,7; T0,10; and T0,11. The high pattern T0,0 was found to be significantly different ($p<.05$) from T0,7; T0,10; T0,6; and T0,11. Other significant differences ($p<.05$) were found between the high patterns T0,9 and T0,7; T0,9 and T0,10; T0,11 and T0,7; T0,11 and T0,10; T0,6 and T0,7.

Paired comparisons for low rhythmic targets also revealed significant differences ($p<.05$) between individual patterns. T0,10 was significantly different to T0,9; T0,0; T0,7 and T0,6. Other significant differences ($p<.05$) occurred between T0,11 and T0,9; T0,11 and T0,0; T0,8 and T0,9; and T0,8 and T0,0.

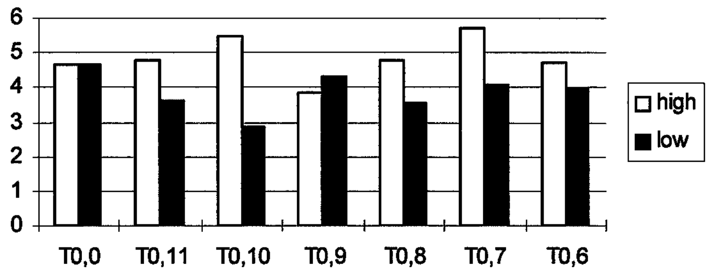
These results suggest that the clarity of registral patterns in *Piano Phase* varies from region to region. The variation in salience, and the possibility of alternative configurations (for example, inclusion of the "B" in the low stream), demonstrate another dimension of ambiguity in Reich's phase-shifting works. The fact that registral beat-class sets vary in salience throughout *Piano Phase* suggests that any regularities in attack-point series (discussed in Chapter 4) may not have a direct impact on listeners temporal experience of the composition. The results reported in this section tentatively provide support for the contribution of rhythmic regularity to the formation of streams. A case for establishing the relationship between schema-based and primitive segregation processes in this music is continued in later sections.

Differences between the clarity of high and low patterns

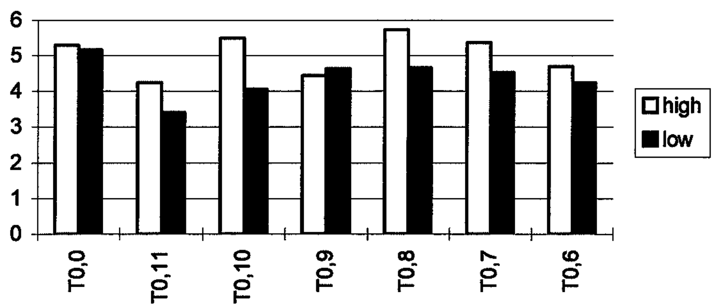
In this section, the mean scores for high targets and low targets are discussed for the seven stimulus patterns. The graphs in Figure 6-13 show the average rating responses in Experiment 2A for high and low patterns across all three presentation rates.

Figure 6-13 Comparing the salience of high and low resulting patterns in each region (Experiment 2A)

139 ms



189 ms



239 ms

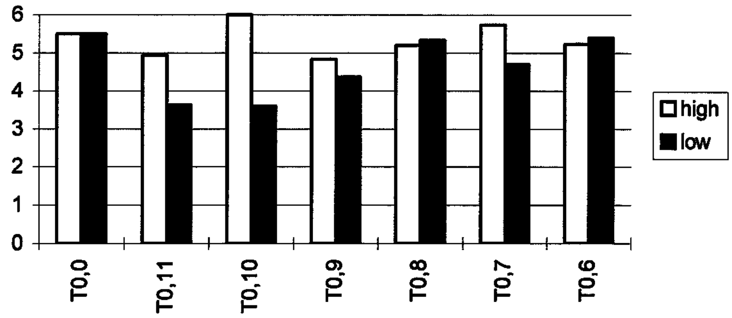


Figure 6-13 shows that, with the exception of T0,0, the salience of high and low patterns differs in each region. On average, there was no difference between the clarity of high and low patterns for T0,0 at 139 ms and 239 ms, and only a very slight difference at 189 ms, where the high stream was more salient. These results reinforce the notion of the free play of the musical system. That is, the principal pattern does not allow either of the two registral figures to dominate perceptually. When simultaneous groupings are generated by phase-shifting however, the ability of one stream to capture notes out of another, or for one stream to reduce the coherence of sequential (registral) patterning may account for the difference between high and low stream responses. In every region, except T0,9, listeners heard the high stream more clearly than the low stream in the two faster presentation rates (IOI = 139 ms and 189 ms). Experiment 1A and 1B in Chapter 5 showed that region T0,9 was unique in terms of perceptual grouping. It was the only region in which the majority of listeners chose the pulse train 3-1 for the global pattern. When individual streams were tested, the low stream evoked the same pulse train, suggesting that the low stream pattern provided the metric framework for the entire pattern.

At the presentation rate 239 ms, T0,8 and T0,6 showed higher averages for the low pattern. Generally however, the high patterns were rated more salient than the low patterns. The largest margin between the clarity of high and low patterns occurred in region T0,10. The difficulty in hearing the pattern formed by the E and F# may be attributed to the tendency for the B to be incorporated into the low stream (see Figure 6-14)

Figure 6-14 Alternative pattern derived from T0,10

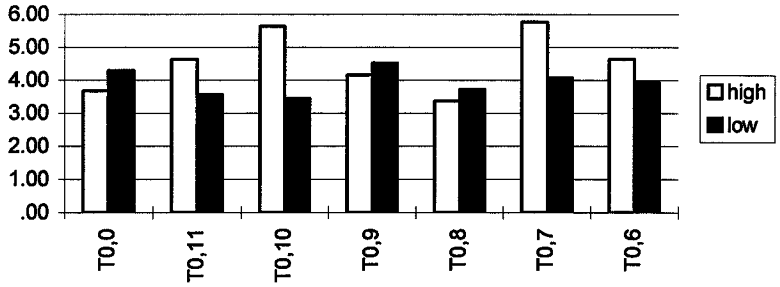
The margin between the salience of high and low patterns in this region is reinforced by the rhythmic simplicity of the high pattern. Experiment 1B demonstrated that overall, low patterns were less ambiguous in terms of listeners' perception of pulse (that is, they did not generate as many different pulse-train responses). The fact that the high patterns were heard as being more isolated than low patterns in Experiment 2A weakens Jones' argument that rhythmic regularity is the principal determinant of streams formation.

A repeated measures analysis of variance was used to determine whether there was a significant difference between the clarity of high and low patterns. The analysis revealed a significant main effect ($p<.05$). Comparisons revealed significant differences ($p<.05$) between the clarity of high and low target patterns for tempo = 139 ms in T0,11; T0,10; T0,8; and T0,7. At the slightly slower rate, significant differences ($p<.05$) were found between T0,11; T0,10; and T0,8. For the slowest presentation rate, significant differences ($p<.05$) between the clarity of high and low target patterns were found between T0,11; T0,10; and T0,7.

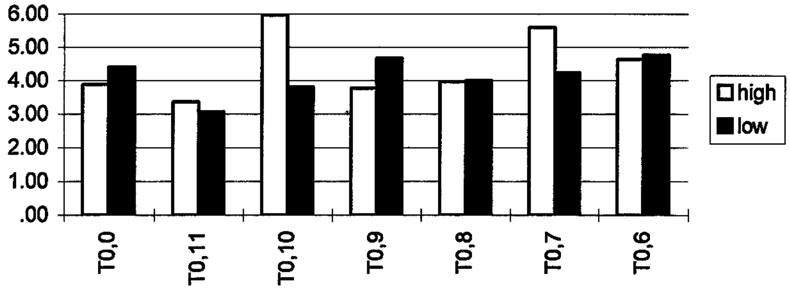
The results in Figure 6-15 show the mean responses for high and low rhythmic patterns in Experiment 2B. The graphs show that in regions T0,11, T0,10 and T0,7, the high beat-class set was more easily distinguished in the global pattern than the low beat-class set. This is consistent across all three tempos. In region T0,9 the low pattern was more salient than the high pattern across all three presentation rates. This result concurs with the clarity of melodic target patterns in Experiment 2A (shown in Figure 6-14). Regions T0,0, T0,8 and T0,6 varied with tempo. Once again, the largest margin between the salience of high and low patterns occurred in T0,10.

Figure 6-15 Difference between high and low patterns in Experiment 2B

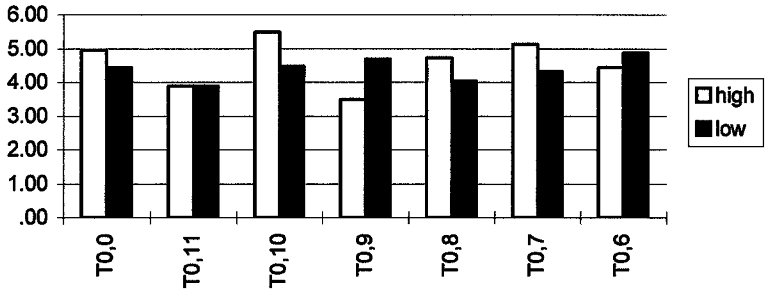
139 ms



189 ms



239 ms



The mean scores for experiment 2B suggest that when rhythm is presented in isolation, the low pattern (beat-class set) becomes easier to isolate than the high pattern in some regions. Testing for type of target pattern, an analysis of variance revealed a significant main effect ($p<.05$). Comparisons revealed significant differences ($p<.05$) between ratings given to high and low patterns in regions $T_{0,11}$, $T_{0,10}$ and $T_{0,7}$ (139 ms), and $T_{0,10}$, $T_{0,9}$ and $T_{0,7}$ at both of the slower presentation rates (189 ms and 239 ms).

Effect of tempo on the clarity of resulting patterns

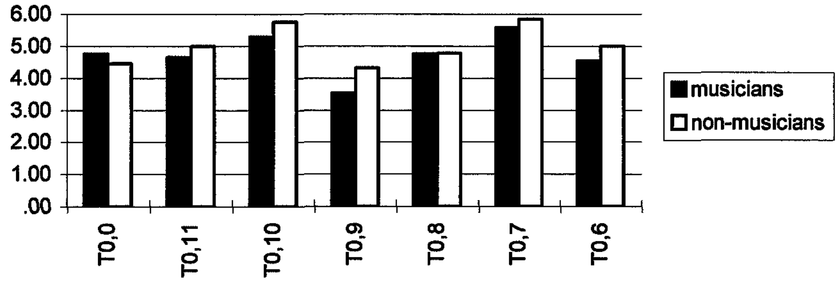
Results for Experiments 2A and 2B do not support the assumption that segregation (the clarity of patterns) increases with pattern rate; a finding that may be attributed to cognitive factors rather than pre-attentive stream segregation. That is, with slower presentation rates, the amount of time listeners have to build a mental description of the pattern could enhance their ability to isolate it in the comparison sequence. Although clarity appeared to increase with tempo for the high rhythmic targets in T0,11; T0,9 and T0,7, an analysis of variance revealed that the target in T0,11 was the only pattern to show a significant difference ($p<.05$) between the three presentation rates. Although these odd numbered regions can be differentiated from even numbered regions (T0,10; T0,8; and T0,6) on a number of levels[21], the reason for their higher means cannot be verified.

Differences between musicians and non-musicians

Musicians and non-musicians were tested in Experiments 2A and 2B to assess the role of musical experience on listeners' ability to isolate resulting patterns from the musical texture in *Piano Phase.*

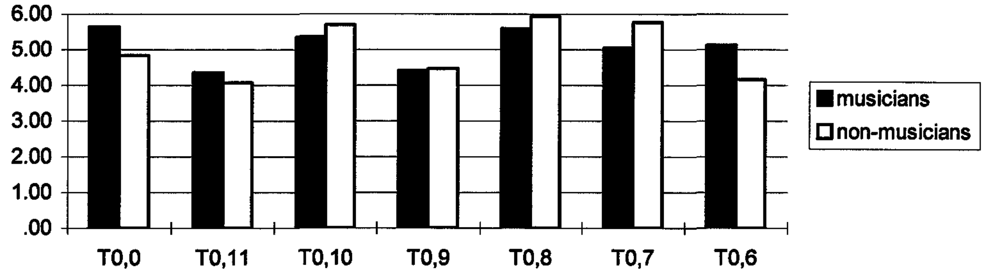
Figure 6-16 Mean scores for musicians and non-musicians for high target patterns (Experiment 2A)

139 ms



[21] Odd numbered regions contain dissonant note pairs, whereas even numbered regions contain largely consonant dyads. Dyads in even numbered regions contain notes from either the {E,B,D} or the {F#, C#} sonority, whereas dyads in the odd numbered regions mix these sonorities. Odd numbered phases do not generate polyphonic or homophonic characteristics, whereas even numbered phases *appear* to enhance the two voice division in terms of texture.

189 ms



239 ms

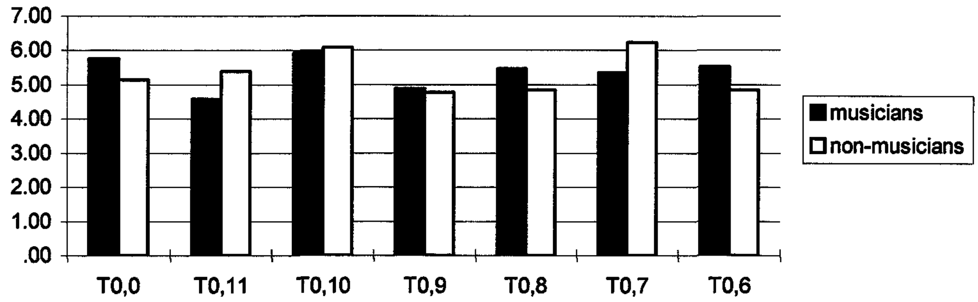
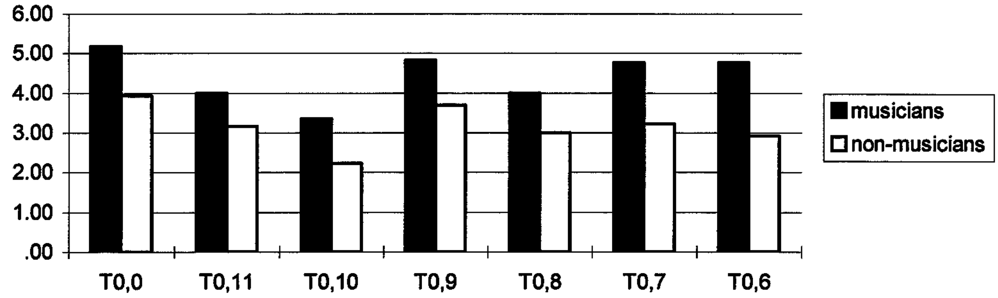


Figure 6-16 shows the means scores for musicians and non-musicians for the high patterns in Experiment 2A. The graphs show that musicians did not consistently hear the high target patterns as more clearly isolated than non-musicians. This was supported by the results of a repeated measures analysis of variance, which revealed *no* significant differences between the performance of musicians and non-musicians.

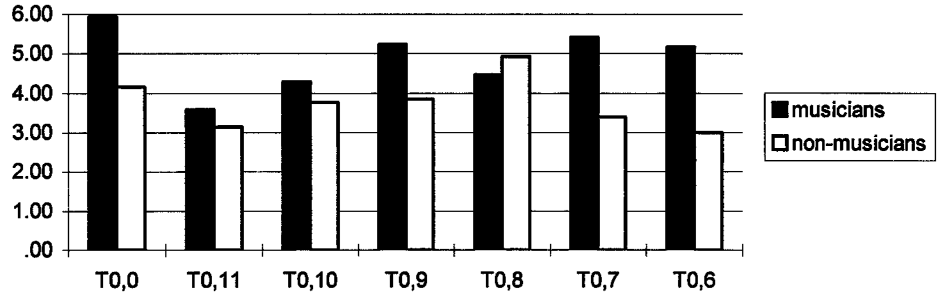
The mean scores for low target patterns for musicians and non-musicians (Experiment 2A) are shown in Figure 6-17. Once again, although the means suggest that musicians rated higher than non-musicians in the majority of trials, an analysis of variance did not reveal a significant main effect for the two subject groups. The only significant difference ($p<.05$) between musicians and non-musicians occurred for tempo = 189 ms.

Figure 6-17 Mean scores for musicians and non-musicians for low targets (Experiment 2A)

139 ms



189 ms



239 ms

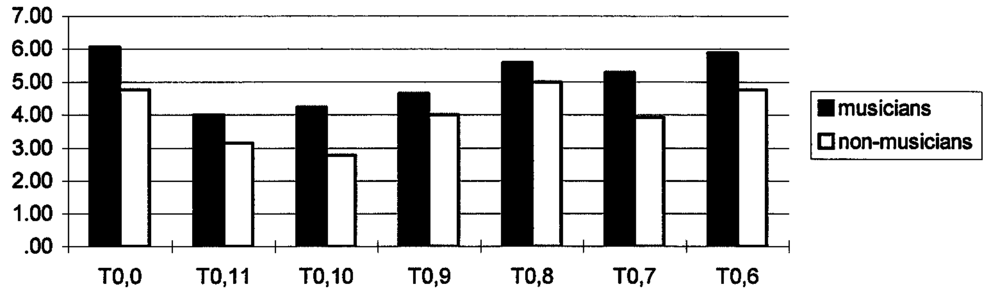
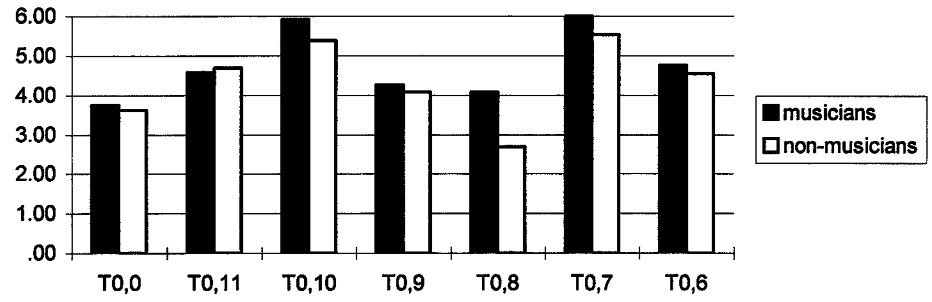


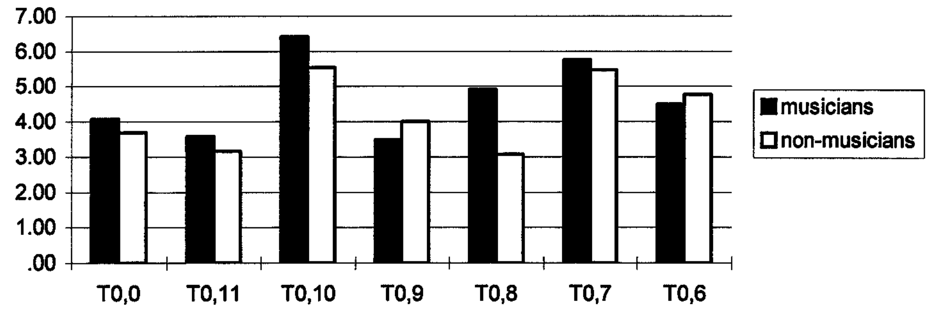
Figure 6-18 below shows the mean responses between musicians and non-musicians for the high beat-class sets in Experiment 2B. With the exception of T0,8, the graphs show little difference between the two groups. Occasionally, non-musicians rated higher than musicians (i.e. 139 ms: T0,11; 189 ms: T0,6 and T0,9; 239 ms: T0,0 and T0,11). Once again however, an analysis of variance did not reveal a significant main effect for subject groups.

Figure 6-18 Mean scores for musicians and non-musicians for high rhythmic targets (Experiment 2B) for all presentation rates

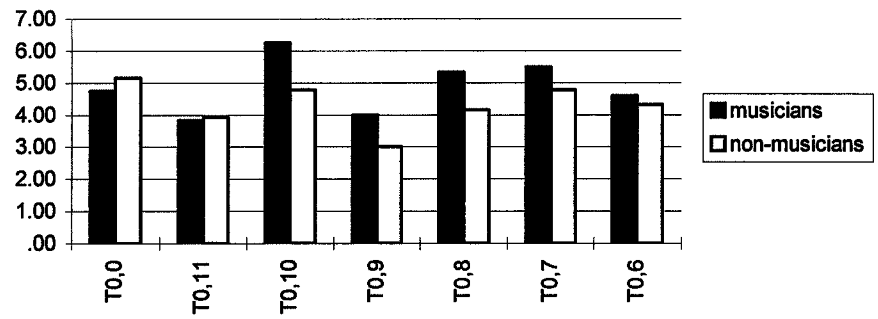
139 ms



189 ms



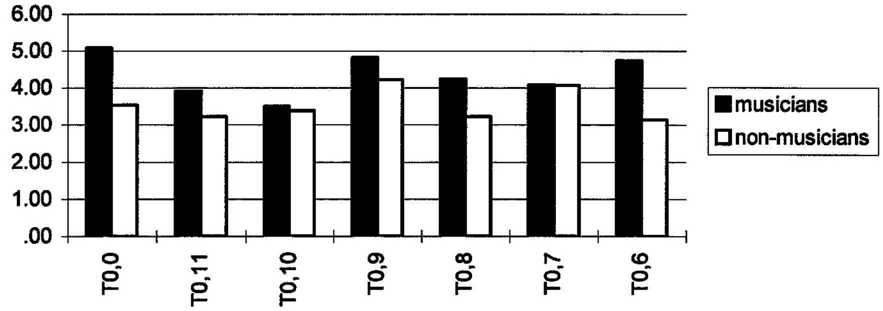
239 ms



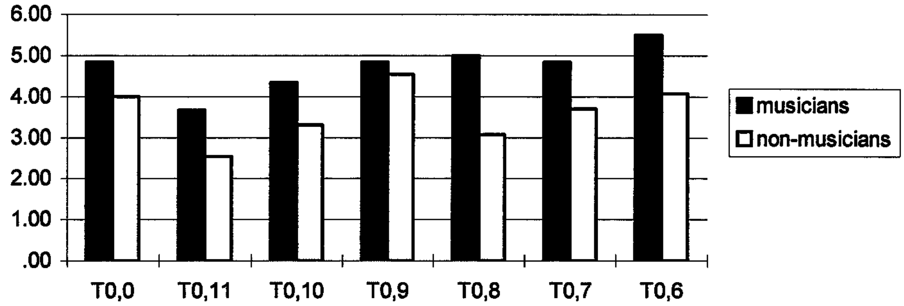
The results for the low rhythmic target patterns in Experiment 2B are shown below in Figure 6-19. With the exception of T0,8 (239 ms), musicians average responses were higher than non-musicians. Although rhythmic target patterns generated a slightly larger between-subject effect (than melodic targets in Experiment 2A), an analysis of variance did *not* reveal a significant difference between musicians and non-musicians.

Figure 6-19 Mean scores for musicians and non-musicians for low rhythmic targets (Experiment 2B) for all presentation rates

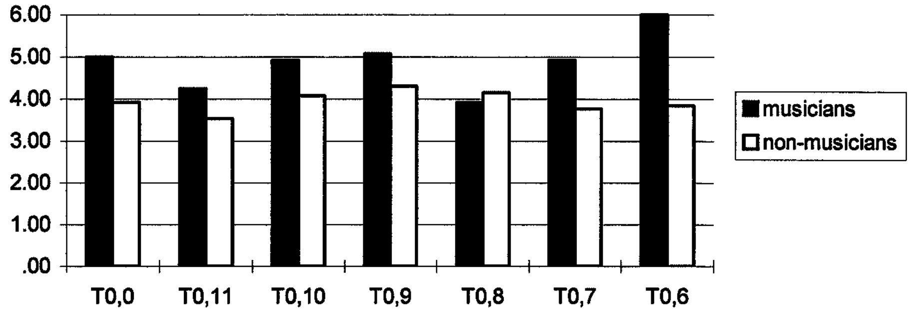
139ms



189 ms



239 ms



The results discussed above all suggest that the ability to segregate patterns from the musical texture in *Piano Phase* is not significantly influenced by musical background. As stated in Chapter 3, a schema-based process "is presumed to involve the activation of stored knowledge of familiar patterns or schemas in the acoustic environment" (Bregman, 1990, p. 397). It is assumed, according to this definition, that through learning and past experience, musicians develop stronger schemas for music than non-musicians. I argue that the lack of external meaning and symbolism in Reich's music minimises the role of schema-based segregation processes, and heightens the role of primitive segregation processes.

Comparing the results of Experiments 2A and 2B

The graphs shown below compare mean responses for melodic and rhythmic target patterns in Experiments 2A and 2B. In the introduction to this chapter, I stated that a strong relationship between mean scores across Experiments 2A and 2B may provide insight into the effect of rhythm (independent of melody) on the strength of stream formation. Figure 6-4 shows mean scores between experiments at the fastest tempo.

Table 6-4 Comparison of results for high target patterns in Experiments 2A and 2B (139 ms)

The prefix "M" indicates melodic pattern, and the prefix "R" indicates rhythmic pattern.

Experiment 2A		Experiment 2B	
MT0,9	3.87	RT0,8	3.36
MT0,0	4.63	RT0,0	3.68
MT0,6	4.73	RT0,9	4.16
MT0,8	4.77	RT0,11	4.64
MT0,11	4.80	RT0,6	4.64
MT0,10	5.50	RT0,10	5.64
MT0,7	5.70	RT0,7	5.76

Table 6-4 shows that in both experiments, listeners found the high patterns in T0,10 and T0,7 the most salient. This suggests that there may be some correspondence between the type of rhythmic pattern and the strength of stream formation.

Similarly, a comparison between the results of Experiment 2A and 2B for the low target patterns (Figure 6-5) demonstrates a tentative relationship in terms of the order of patterns from lowest to highest mean score. In addition, the results for regions T0,6; T0,7; T0,8, and T0,0 show very similar means for the two experiments, with the rhythmic target patterns generating marginally lower scores. Therefore, although rhythmic beat-class sets were slightly more difficult to isolate than melodic target patterns, the order (from not clearly isolated to very clearly isolated) was generally reflected across experiments.

Table 6-5 Comparison of results for low target patterns in Experiments 2A and 2B (139 ms)

The prefix "M" indicates melodic pattern, and the prefix "R" indicates rhythmic pattern.

Experiment 2A		Experiment 2B	
MT0,10	2.87	RT0,10	3.44
MT0,8	3.57	RT0,11	3.56
MT0,11	3.63	RT0,8	3.72
MT0,6	3.97	RT0,6	3.92
MT0,7	4.10	RT0,7	4.08
MT0,9	4.33	RT0,0	4.28
MT0,0	4.63	RT0,9	4.52

Summary

This chapter reported two experiments which were designed to measure the salience of resulting patterns in Reich's *Piano Phase*. The results of the experiments demonstrated that the salience of resulting patterns is not consistent throughout prolongation regions. In accord with Jones (1981), there was evidence to suggest that regular patterns formed more coherent auditory streams. This finding however, may be attributed to the nature of the experimental task, which required listeners to form a mental description of a pattern, and then rate its clarity within the comparison pattern. That is, the finding may be attributed to the fact that regular patterns are coded (remembered) more easily than irregular patterns, and therefore easier to isolate when surrounded by other sounds.

A more pertinent feature of the results was the finding that musical experience did not seem to enhance listeners' ability to isolate target patterns. This provides evidence that the perception of patterns in Reich's music is not based on formalism (knowledge of the formal characteristics of music). In addition, it provides support for the multi-dimensional approach to musical temporality in this study, which provides both objective (formal/analytic) and subjective (empirical/experiential) views.

In Chapter 2, I demonstrated that Reich's early works do not consist of structural elements which set up expectations, or allow predictions about future events. When we consider that musical schemas result from a knowledge of musical structure, we would not expect them to play an important role in Reich's early works. The results of the experiments reported in this chapter support this assumption. In addition, they concur with the idea that by stripping music of external symbolism and referential meaning, primitive segregation processes adopt a heightened role in listening. Although I argue that *musical schemas* are not responsible for the perception of resulting patterns in Reich's phase-shifting music, schema-based (attentional) segregation processes allow the listener to select sub-patterns from within auditory streams.

Chapter 7

Canon, Counterpoint and Complexity

Introduction

The investigation of perceptual processes in Reich's phase shifting works provides a basis for examining the interaction between linear and non-linear elements in several of his later compositions. The aim of the first section of this chapter (Freezing the Play of the System), is to demonstrate that certain perceptual features of the phase shifting works remain strong temporal forces in Reich's later compositions, despite the introduction of more expansive melodies, harmonic movement, and more extensive use of the orchestra. The perceptual characteristics of the phase shifting works are compared with a number of Reich's later works, written between 1970 and 1986.

In the second part of the chapter (The Minimalist 'Technique'), the examination of Reich's more recent works is used to argue that a definition of minimalist music should be extended to accommodate later developments of the original minimalist aesthetic. In particular, I argue that such a definition would permit a greater appreciation of the influence of the minimalist 'technique' on the work of more recent composers.

In section three of the chapter (The 'New Complexity'), Reich's music is examined in relation to the 'new complexity'. The discussion highlights the relationship between Reich's music, and the work of more recent composers, whose interest revolves around how a listener's perceptual ordering processes respond to ambiguous musical environments.

Freezing the Play of the System

Based on correspondences between figure/ground reversal in vision, and Derrida's notion of 'deconstruction', introduced in Chapter 2, I suggested that Reich's phase shifting compositions resemble a system of instability, where patterns appear to emerge randomly from the past, and dissolve into the future. I have used the term 'inter-text' to conceptualise the space in between two or more available patterns. This space is responsible for the dynamics of the system, in particular, the capacity for patterns to emerge with or without the listener's volition. Through the absence of structural cues, the phase shifting compositions represent a decentralised system, or a system in which the central term is constantly subverted. Because the play of the system is not arrested, the phase shifting compositions present us with a series of alternating views, which may emerge of their own accord.

This section of the chapter considers the extent to which Reich's later works demonstrate a tendency toward 'freezing the play' of the musical system. That is, it considers the degree to which Reich compromises levels of perceptual ambiguity in favour of more definitive percepts, or alternatively, how he accommodates ambiguity despite the presence of more linear features. The aim of the discussion is to consider the perceptual characteristics of interlocking structures and 'resulting patterns' when combined with more expansive melodies, and other progressive features of Reich's later works. This inquiry provides an opportunity to examine the interplay between linear and non-linear forces in the music, and to assess the changing relationship between primitive and schema-based organisational processes.

With the exception of *Four Organs* (1970), all of Reich's compositions up to 1971 use the phasing process in its slow shifting form. *Four Organs* is organised according to a different rhythmic technique, which is developed in several later works. The technique involves the gradual augmentation of individual notes within a single chord (see Figure 7-1).

Figure 7-1 ***Four Organs*** **for 4 electronic organs and maracas, (1970); bars 1-8**

Source: Universal Edition (London), 1980

Like the phase shifting compositions, this technique was influenced by the electronic medium. In particular, it was an extension of the idea presented in *Slow Motion Sound* (1967).[22] The augmentation process used in *Four Organs* also resembles the phase shifting process in the sense that it unfolds very gradually. The listener, however, is able to recognise and anticipate the gradual lengthening of the chord over

[22] Reich's *Slow Motion Sound* (1967) involves slowing down a recorded sound very gradually to many times its original length while keeping the pitch and timbre constant.

time. The dislocation of individual notes from the context of the complete chord creates a fragmenting effect, which demonstrates Reich's continued interest in 'pointing out' sound events which are otherwise embedded in a more complex structure. In addition, some of the displaced notes, played on different instruments, may be heard as being produced by a single organ. Therefore, while 'resulting patterns' are not the focus of this composition, Reich's specification that the timbre of the four organs must be identical, sets up the potential for this type of ambiguity.[23] While *Four Organs* is the first of Reich's compositions to generate this level of expectation, it adheres closely to the idea of "Music as a Gradual Process", in the sense that there are no changes of pitch, timbre, or dynamics in the entire work.

Alterations of timbre however, are introduced in *Drumming* (1970-1), which was composed around the same time as *Four Organs*. This work consists of four sections, which are not separated by a pause. Consistent with earlier works, the first three sections of the composition focus on particular groups of instruments. This reflects Reich's continued interest in 'resulting patterns', which emerge through the layering of patterns played on identical instruments. In contrast, the fourth section of the composition, utilises the full orchestra:

I	four pair of tuned bongo drums and male voice
II	three marimbas and female voice
III	three glockenspiele, whistling, and piccolo
IV	all instruments and voices combined

In *Drumming*, Reich adapts the phase shifting process, but also introduces several different techniques which become important in later works. The first is the technique of gradually substituting beats for rests, or rests for beats. The second technique is the gradual transition from one timbre to another, while keeping the pitch and rhythm constant. The third notable feature of the composition is the simultaneous combination of instruments with different timbres, and the fourth is the

[23] Perceptual ambiguity is promoted further by the spatial configuration of amplifiers and loud speakers in a live performance.

imitation of different instruments using the human voice. The first of these processes, that of replacing rests with beats, is illustrated in Figure 7-2.

Figure 7-2 ***Drumming*** **(1971); bars 1-8**

The rhythmic pattern played by four tuned bongo players is gradually constructed in the first eight bars of *Drumming*. Each measure is repeated at least six times, until the pattern is fully constructed at measure 8. At the end of section one, the same pattern is played out of phase by three of the drummers. The transition to section two is marked by the entry of three marimba players, who also perform the principal pattern out of phase. Gradually, the drummers fade out so that only the marimbas remain. By changing only one parameter, while keeping the rhythm and pitch constant, Reich draws attention the influence of timbral change on the perception of the basic pattern.

The transition from section two to section three duplicates this effect. That is, the glockenspiele double the same pattern as the marimbas, which then fade out gradually. This time however, the transition includes a change of register, where the glockenspiele in their lowest range imitate the pattern played by the marimbas in their highest range. Once again, this minimal transition, which maintains the same rhythm and pitch structure, allows the listener to become aware of how timbre effects the dynamics of the pattern.

When the basic pattern is played out of phase on the tuned bongos, individual percussive components of the drum sound have the tendency to segregate from the rest of the texture. The marimbas in section 2, which have a more precise pitch, generate 'resulting patterns' similar to those found in earlier works. The listener may hear these sub-patterns as discrete cells, or alternatively, may reintegrate them into the context of the basic pattern. Occasionally, the repetition of a single note will surface strongly as an individual stream which appears to bear little or no temporal relationship to the interwoven fabric created by the remaining parts. In section three, the extremely high pitch range of the glockenspiele may result in the clear segregation of the percussive component of the sound.

Consistent with the phase shifting compositions, there are no harmonic changes in *Drumming* to support movement toward a goal. The rhythmic developments, and transitions of timbre between sections, create a degree of movement in the piece, however this movement is still very gradual. In accord with the phase shifting works, smaller surface details (produced by interlocking structures) have the capacity to dissolve larger structural cues, such as changes in timbre, and the construction of the basic pattern.

Reich's continued interest in perceptual ambiguity is further demonstrated in *Drumming* by the imitation of instrumental patterns using the voice. For example, sounds such as "tuk", "tok", and "duk" are used to articulate resulting patterns by imitating the sound of the drums. In the second section, female voices imitate marimba patterns, using "bu" or "du" sounds. In the third section, whistling and piccolo (for the highest ranges) imitates patterns formed by the interlocking of the glockenspiel parts. In particular, these sounds blend with the high residual ring produced by the glockenspiele in their upper register. In the fourth section of *Drumming*, the imitative vocal techniques used in previous sections are combined. Doubled patterns are selected during rehearsal time, along with the order in which they are played (Reich, 1974). Reich specifies that the "most musical" patterns within the texture should be chosen for doubling. The result, as in *Phase Patterns* and *Violin Phase*, is that of bringing something transitory into the realm of reality.

While Reich continues the practice of constructing interlocking patterns on identical instruments in the first three sections of *Drumming*, the fourth section combines all instruments and voices previously heard in the composition. The reconstruction of the basic pattern in this section, using different timbres, significantly fragments the now familiar pattern into smaller discrete units, exclusive to instrument type. The same rhythmic pattern is played on all instruments throughout the section, however each group of instruments (drums, marimbas, and glockenspiele) articulate the rhythmic pattern using a different set of notes. At different times in the composition, one of the instrumental groups will play the primary pattern out of phase, drawing attention to the detailed activity in that part:

> When one marimba phases against another, they create an overall marimba pattern that is clearly distinguishable from the drums and glockenspiels. It is a similar situation when one drummer phases against the other drummers, or when one glockenspiel player moves ahead of another. (Reich, 1974, p. 61)

While *Drumming* represents an important transition in Reich's compositional development, in terms of orchestral use, and the introduction of a range of different techniques, many of the ideas central to the phase shifting works are retained. By imitating melodic sub-patterns using voices, the effect of patterns emerging from a relatively static framework remains an important feature of this work. In addition, the manipulation of a single pattern, resulting in a complex array of sounds, reflects a technique central to Reich's earlier compositions.

Six Pianos, and *Music for Mallet Instruments, Voices and Organ*, both composed in 1973, combine several of the techniques used in *Drumming*. Initially, Reich experimented with a larger number of instruments for the material in *Six Pianos*. However, he found that too many instruments compromised the clarity of the intricate rhythmic patterns he intended. The choice of six small spinet pianos, or small grands made this clarity possible (Reich, 1974).

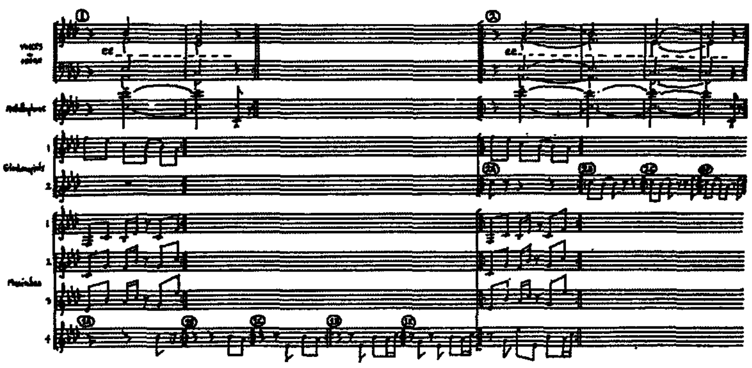
Figure 7-3 ***Six Pianos*** **(1973); bars 1-8**

Source: Reich, 1974, p. 68

In the opening section of *Six Pianos* (1973), pianos 1, 2, and 3 begin playing the same rhythmic pattern, using different notes, while piano 6 doubles piano 1 (Figure 7-3). In unison, pianos 4 and 5 begin the process of constructing one of the other piano parts gradually, by substituting rests with beats. This time however, the pattern is constructed two quaver beats out of phase. Unlike in *Drumming*, where the process occurs in isolation, the rhythmic construction in *Six Pianos* appears in a different rhythmic position against the pre-existing structure. As the number of interacting parts increases in this composition, the listeners attention may be drawn to individual strands of the texture, for example, the repetition of a single note. Due to the complex relationship between the six instruments, it is more difficult to actively isolate melodic sub-patterns. In particular, the chordal nature of the piece tends to restrict the segregation of sequential (proximal) notes from their vertical context. At different stages, the listener may direct their attention to the rising and falling contour created by the succession of chords, or to the layering of individual strands of sound.

The opening two bars of *Music for Mallet Instruments, Voices and Organ* (1973), shown in Figure 7-4, also demonstrates the process of reconstructing a pre-existing pattern beat by beat, at a different rhythmic transposition. That is, while three marimba players perform the same rhythmic pattern at different melodic transpositions, the fourth marimba is introduced gradually by duplicating notes of the third marimba, three quaver beats out of phase.

Figure 7-4 ***Music for Mallet Instruments, Voices and Organ*** **(1973); bars 1 and 2**
Source: Reich, 1974, p. 69



The presence of interlocking structures in this piece creates the potential for 'resulting patterns'. However, in this composition, the simultaneous activity of the glockenspiele and the chordal augmentation of the voices, organs and metallaphone, reduces the extent to which resulting marimba patterns can be isolated in the texture. The construction of the pattern played by the fourth marimba, in which rests are gradually replaced by notes of one of the existing patterns, can be followed by the listener, despite the pre-existing patterns of the three marimbas. However, when the pattern is secured in its phased position in bar 2, the marimba parts become exceedingly intertwined.

The ability to clearly isolate discrete sub-patterns in this piece is diminished by the almost immediate introduction of the voices and organs. The first augmentation of this chordal progression in bar 2 is easily distinguished. As in *Four Organs* (1970), the listener is able to recognise and anticipate further augmentation as the piece progresses. A listener attuned to this aspect of the music becomes engaged in a comparatively linear process, where expectation enhances the sensation of forward movement. Throughout the composition, however, the listener's attention is directed toward resulting patterns which are highlighted by vocal doubling. The process of pointing out patterns draws attention to configurations embedded within the interlocking texture. Due to the simultaneous activity of the voices and organs, these patterns may not be heard until they are pointed out. The first augmentation of the voices and organ coincides with the complete rhythmic construction of the fourth marimba in measure 2 (see Figure 7-4). These simultaneous processes can be seen as two conflicting directional forces, where the increased internal activity of one part runs parallel with the gradual lengthening of another.

While there is still a considerable amount of 'free play' in *Music for Mallet Instruments, Voices and Organ*, the audibility of the augmentation process (in the voices and organs) gives the listener the opportunity to enter into a relatively linear process, rather than entering into the 'verticality' of the piece. However, there is enough space between sustained chords for the listener's attention to be pulled back into the circular play of the mallet instruments. A different kind of perceptual ambiguity in this composition is created by the pairing of the organ and women's voices (singing an "ee" sound) in this piece, which are difficult to differentiate.

In Reich's earlier phase shifting pieces, "psycho-acoustic by-products" were defined as the resulting patterns generated by the interlocking structures of identical instruments. While this is still the case in *Music For Mallet Instruments*, other types of "psychoacoustic by-products" may be experienced. For example, when the chords sounded by voices and organ are held in awareness, residual sounds generated by the striking of mallet instruments can be heard. This effect is similar to that experienced in the drum and glockenspiel sections of *Drumming* (1970-71).

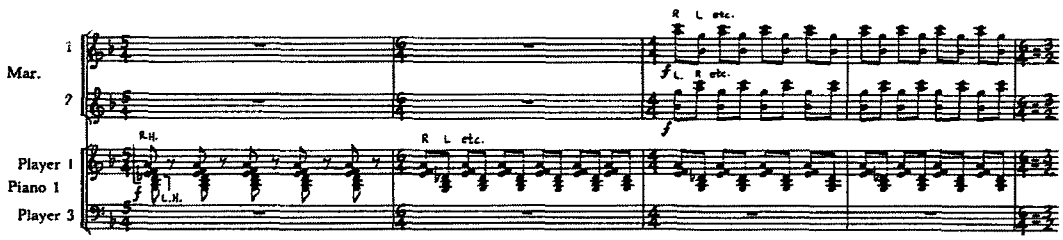
In summary, *Drumming* (1970-1), *Six Pianos* (1973) and *Music for Mallet Instruments, Voices and Organ* (1973) maintain many of the 'free play' characteristics of the earlier phase shifting works. While perceptible processes such as rhythmic construction, phasing, and augmentation unfold in a somewhat linear fashion, the self-replicating nature of these works maintains a level of surface complexity, which prohibits a strong sense of forward motion or goal-directedness.

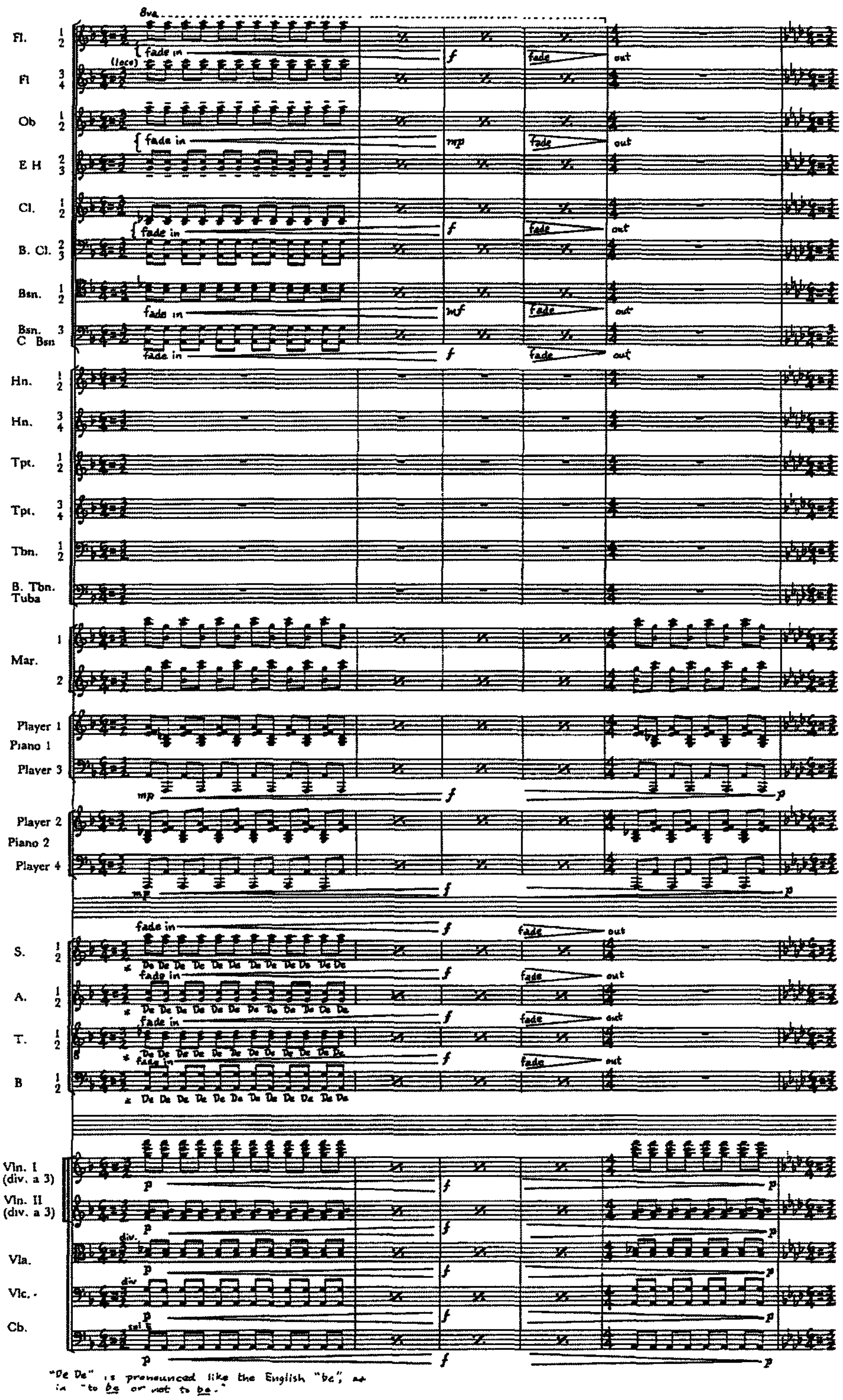
Compositions written after *Music for Mallet Instruments, Voices and Organ* (1973), which are discussed below, continue to incorporate perceptual ambiguity to some degree. The following discussion considers how such ambiguity is accommodated in these works, with the introduction of more expansive melodies, regular harmonic movement, and more extensive use of the orchestra.

In the opening section of *The Desert Music* (1984), the listener is exposed to two alternating effects. The first is the fast 'rocking' figure introduced by the piano in bar two, and marimbas in bar 3, and the second is the echoing effect produced by the voices and wind instruments, which to a certain extent stabilises that rocking movement (see Figure 7-5).

From bar 5, the alternation of dyads in the piano and marimba parts work in opposition, in the sense that the ascending quaver pairs in one part are counteracted by descending quaver pairs in another part. The voices, strings and winds, which gradually fade in and out of the texture, create the impression that they are emanating from the existing interlocking structure. This effect, in which sounds rise to the surface of the texture, is characteristic of earlier works, in which patterns contained within existing frameworks are illuminated. Unlike earlier works, however, pitch combinations in *The Desert Music* change every four or five measures.

Figure 7-5 ***The Desert Music*** **(1984); opening section**





In this composition, perceptually ambiguous events are combined with more extended melodies. In comparison with earlier works, melodies are heard in relative isolation, at least for a short time. For example, at measure 21, a melody played at the interval of a sixth is introduced by two violins and synthesisers (see Figure 7-6).

Two additional violins and synthesisers however, quickly upset the rhythmic stability of these patterns. That is, the clear articulation of the melody is replaced by a process which accentuates different parts of the melody at different rhythmic transpositions.

Figure 7-6 ***The Desert Music*** **(1984); measure 21**

Introduction of the melody

When this rhythmic and melodic interplay reaches a level of saturation, through extreme fragmentation and layering, it becomes the new static background for the reintroduction of the voices at measure 26 in the score (see Figure 7-7).

Figure 7-7 ***The Desert Music*** **(1984); measure 26**

Introduction of voices

The melody introduced in the bass voice in the second movement of the composition is one of the clearest examples of Reich's use of extended melodic passages (see Figure 7-8), which begin to feature more strongly in later works. The melody, which is doubled by bassoon and clarinets, is combined with repetitive pulses in the maracas, sticks, vibraphones, and marimbas. This combination, of more expansive melodies and constant repetitive pulses, is characteristic of Reich's later style, and demonstrates a more balanced relationship between the presence of linear and non-linear temporal forces.

Figure 7-8 ***The Desert Music*** **(1984); measure 61**

Introduction of bass vocal melody

Another example of melodic distinction is apparent in the cello and violin parts at measure 117 in the third movement of the piece (see Figure 7-9). Once again however, this distinctness is gradually replaced by ambiguous reflections of the melody. That is, the second cello and violin begin echoing fragments of the melody, until they end up in canon, only one quaver beat apart. The canonic activity in this section is completely self-referential up to measure 120. That is, like in the phase shifting compositions, the melodies in canon are not clearly differentiated by transposition, variation, or timbre.

Figure 7-9 ***The Desert Music*** **(1984); measure 117**

The canonic activity increases with the addition of a third cello and violin, which enter on the very next quaver beat in the cycle. Over the top of this canonic activity, begins the same process in the flutes and first violins. These parts maintain the same rhythm as the existing melody, but introduce a different pitch sequence in a higher octave. The new melody is clearly audible, but only for a short time, until the same 'mirroring' treatment occurs. When all parts are playing together, the registrar span, and the melodic sequences, create a series of arpeggiated passages which flow through all instruments, due to their close distance in the canon. This cascading effect, which results from pitch trajectories rather than grouping by timbre, makes it difficult for a listener to sustain attention to any one part.

Once again, the point of saturation (resulting from extreme overlapping) coincides with the re-introduction of the voices at measure 123. Throughout this section of the music, the rhythmic patterns played on the vibraphones contribute to the ambiguity of the perceived downbeat. However, the wide pitch intervals at cadence points on "say to them" in the vocal writing at figure 150 introduce a sense of breadth and goal-directedness that overrides the close rhythmic and melodic activity in the vibraphone and glockenspiel parts.

The sense of forward motion predominant in the homophonic vocal section, is soon interrupted by the setting of a three-voice canon at measure 160. At measure 161, a second three-voice canon is added, which doubles the rhythm of the first using a different melody. The extreme overlapping of a single text phrase in this section of the music is strongly reminiscent of the effect created by Reich's early vocal tape loop pieces (*Come Out* and *It's Gonna Rain*). That is, individual words and syllables become audible, but their context in the phrase is lost. As the canon builds, the successive voice entries become increasingly difficult to identify. The doubling of the vocal melody on the piccolo, oboe, and clarinet in different registers further prohibits the audibility of distinct vocal lines.

While *The Desert Music* is characteristic of Reich's tendency to "freeze the play of the system" in later works, the perceptual ambiguity generated by interlocking structures, and the extreme overlapping of vocal lines remain strong temporal forces in the music. The music combines strongly progressive features, such as regular harmonic movement, dynamics, extended melodic passages, and phrase structuring, with the static interplay of melodic and rhythmic fragments.

Tehillim (1981)[24], which is based on the setting of a Hebrew text, places more emphasis on extended melodies and harmonic activity than any of Reich's earlier works discussed in this section. The composition is written for four women's voices, piccolo, flute, oboe, English horn, clarinets, organs, strings and percussion. *Tehillim* demonstrates a significant shift in the balance between perceptual ambiguity and structurally progressive features. The first movement introduces a vocal melody, accompanied by tambourine and hand clapping. The rhythm played by these instruments regularly coincides with the rhythm of the melody. Soon after the opening section, clarinets 1 and 2 double the melodic line, which dominates the texture. Throughout the section, the vocal melody participates in a series of canons. The first, a two-voice canon, is doubled by clarinets, and accompanied by sustained notes in the strings, which are broken occasionally to articulate the vocal rhythm. Later in the section, the vocal melody participates in a four-voice canon. In contrast to Reich's canonic treatment in *The Desert Music,* the voice entries in this section, which are doubled by organs 1 and 2, are clearly audible. In particular, this is due to the comparatively wider placement of voice entries (see Figure 7-10).

The melodic setting of the text in the second movement of the composition occurs in two and three voice harmony. The vocal melodies, which are doubled by oboes, English horn and bassoon, are presented homophonically throughout the section. Simultaneously, long sustained chords are present in the strings, and the tambourine and hand clapping parts often reinforce the rhythmic quality of the vocal melody. Throughout this section, the setting of the text becomes increasingly melismatic. The third movement of *Tehillim* begins in a vocal duet, which later expands to four voices. The slow tempo of the movement enhances the clarity of the overall texture. The shift in balance from perceptually ambiguous structures in Reich's early works, to clearly defined melodic lines in *Tehillim,* can be explained by Reich's desire to "set the text in accordance with its rhythm and meaning" (*Tehillim,* cover notes, 1981).

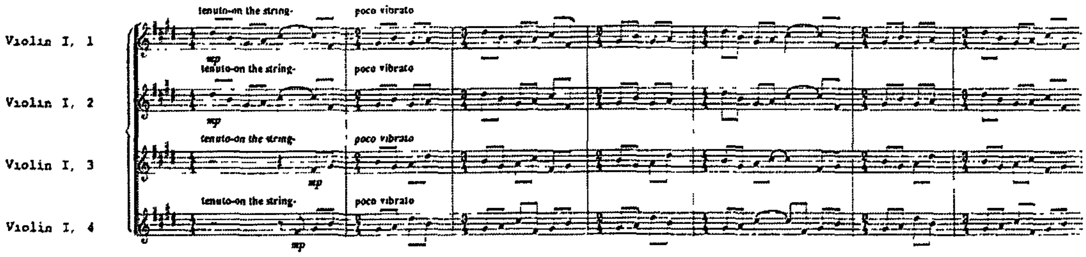
[24] The English translation of *Tehillim* is 'psalms', or more accurately, 'praises'.

Figure 7-10 ***Tehillim*** **(1981); four-voice canon in section one**

Source: *Tehillim*, Hendon Music, 1981, p. 27

Unlike in *Tehillim* (1981), the melodic overlapping in *The Four Sections* (1987) generates considerable blurring between instrumental lines. As in *The Desert Music* (1986), the listener is presented with a series of melodies, which, through extreme overlaying, gradually reach a point of saturation.

Figure 7-11 ***The Four Sections* (1987); section 2 opening canon**



For example, in the opening section, individual melodic lines are subsumed by the similarity between the overlapping melodies (see Figure 7-11). Violins 3 and 4 are presented in a two-voice canon, separated by one quaver beat, while violins 1 and 2 play in unison. The similarity between the melodic passages results in a considerable degree of transference between parts. For example the consecutive notes *g* and *a*, which appear in all parts, may be heard as continuously alternating pattern. The close proximity of these notes makes it possible to hear them as a single coherent stream.

By contrast, the high string melody at measure 13 is clearly heard above the remaining string parts, which are woven in a tight configuration. Here, Reich uses dynamics to segregate the high string melody, which takes on a far more expressive, solo quality than those in previous works. As in *Tehillim*, long sustained chords are present in the bass strings and brass instruments for extensive sections. The fact that the canons in this composition occur between related instruments, in this case strings, enhances the transference of melodic motifs between parts. While melodic and rhythmic repetition and overlapping characterise this work, the use of long crescendos, textural expansion, and harmonic changes, create a feeling of a growing tension and progression throughout the first movement of *The Four Sections*.

In the opening of the second movement (measure 48), vibraphones 1 and 2 interact in a circular format, where the second vibraphone imitates fragments of the melody in close succession. The sense of forward movement in the section is initiated by the introduction of the percussive piano chords, which join the vibraphones at measure 55 (see Figure 7-12).

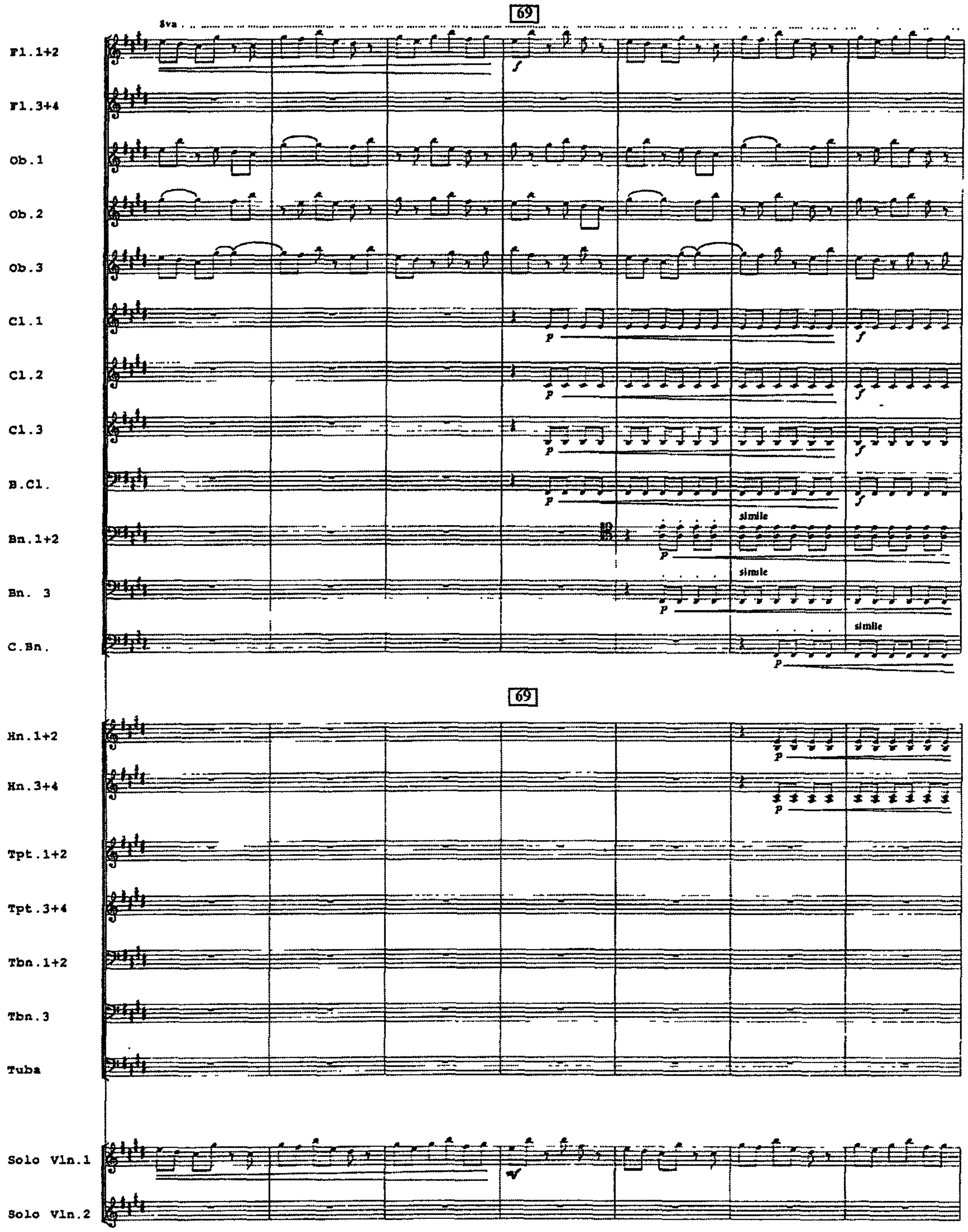
Figure 7-12 *The Four Sections* **(1987); second section, measure 52**

In section three, the oboe plays a clearly isolated melody which is then imitated in the same register by a second oboe. In contrast to section one, the distance separating the melodies in the canon is much broader (three bars). The sense of progression initiated by these more expansive melodies is interrupted at measure 69, with the introduction of the brass and winds. The gradual fading in and out of a repeated chord, spread across a range of instruments, is reminiscent of the effect created in the opening section of *The Desert Music* (see Figure 7-13).

The final movement of *The Four Sections*, like the final movement of *Drumming* (1971), utilises the full orchestra. In section four, the musical texture is divided more clearly. For example, at measure 118, the texture comprises low percussive chordal attacks in the piano, high sustained notes in the violins, and in between these registral extremes, interlocking patterns played on the marimbas and vibraphones. Here, the texture is characterised by the distinctive activity in each of the instrumental groups. Therefore, while *The Four Sections* demonstrates Reich's tendency toward 'freezing the play of the system', the minimalist technique remains an active and influential force in the composition.

The discussion above has demonstrated that, with the possible exception of *Tehillim* (1981), elements of the phase shifting compositions, such as perceptual ambiguity, the use of interlocking structures and 'resulting patterns', and the gradual distortion and fragmentation of melodic motifs, remain important features in Reich's later works. In addition, the later works continue to draw attention to how our perceptual grouping processes respond to ambiguous states. Based on the examples discussed above, the following section considers the extent to which current definitions of minimalism accommodate Reich's compositional development.

Figure 7-13 ***The Four Sections*** **(1987); measure 69**



The Minimalist 'Technique'

The terms 'aesthetic', 'style' and 'technique' have all been used to define minimalism in music (Johnson, 1994). While the terms style and aesthetic have been appropriate for distinguishing various stages of the development of minimal music, they no longer represent more recent music which is given the minimalist label. Johnson

(1994) argues that the "discomfort many composers now feel from being associated with the term may be attributed mainly to its delineation as an aesthetic or a style" (p. 742). In the following discussion, the appropriateness of the term 'technique' in relation to minimalism is demonstrated in view of Reich's more recent compositional developments. In support of Johnson (1994), I argue that by recognising minimalism as a technique, aspects of minimalism in Reich's music can be identified as significant temporal forces in broader compositional frameworks, which incorporate more extensive melodies and elements of goal-directedness.

Elaine Broad (1990) describes minimalism as an aesthetic, which is distinguished by the "conception of the *non-narrative work-in-progress*" (p. 51-52). The term "non-narrative" characterises many early minimalist works, which are concerned with the interplay of small rhythmic and melodic motifs, or long held tones, rather than with the progressive relationship between successive events. In addition, Broad's definition highlights the audibility of musical processes. While perceptible processes characterise Reich's phase shifting compositions, the composer admits that they become less important in his later works (Reich, 1974). *Drumming* (1970-1) was the last of Reich's compositions to utilise the phasing process in its slow shifting form. In later works, rhythmic and melodic patterns continue to occur at different rhythmic transpositions, however, the process does not determine the entire compositional structure. Similarly, while the process of gradually constructing a rhythmic pattern (by substituting rests for beats) in *Music for Mallet Instruments* (1973) is an audible one, it does not determine all that results.

Wim Mertons (1983) also defines minimal music by distinguishing it from goal-directed music. For example, he states that:

> Traditional dialectical music is representational: the musical form relates to an expressive content and is a means of creating a growing tension... But [minimal] music ... is non-representational and is no longer a medium for the expression of subjective feelings. (Mertons, p. 88)

Once again, this definition accurately describes Reich's earlier phase shifting works, which, through their lack of harmonic movement and phrase structuring, avoidance of traditional beginnings and endings, and limited pitch material, do not generate a sense of tension and release traditionally associated with music listening. For the same reasons, compositions such as Terry Riley's *In C* (1964), and La Monte Young's *Trio For Strings* (1958), are well accommodated by Mertons' definition. Many of Reich's later works, however, such as *The Desert Music* (1984), *The Four Sections* (1987) and *Different Trains* (1988), are no longer supported by this definition. While elements of the minimalist aesthetic remain important in these works, Reich introduces more expansive melodies, dynamic variation, and harmonic movement, which can be interpreted as "the expression of subjective feelings". For example, in the first movement of *The Four Sections* (1987), the use of long crescendos, textural change, and more regular harmonic movement creates a sense of "growing tension" and forward progression.

The definition of minimalism as a 'style', has been advocated by writers such as John Rockwell (1983) and Edward Strickland (1993). This definition encompasses a much broader range of works, because it is not restricted to compositions based purely on musical processes. In addition, it includes minimalist music which exhibits some degree of representation and goal-directedness. The definition of minimalism as a 'style' draws attention to aspects of form, harmony, melody, rhythm and texture, which are common to the music of a group of composers, namely, Steve Reich, Terry Riley, Philip Glass and La Monte Young:

> The form of pieces in the minimalist style is primarily continuous, often in the shape of an unbroken stream of rhythmic figuration flowing from the beginning of the piece until it ends. Sometimes these continuous forms grow gradually from sparse rhythmic frameworks or wane after reaching climaxes. However, in any case, distinct disjunct sections are generally not characteristic of the minimalist style. The texture... typically consists of interlocking rhythmic patterns and pulses continuing without interruption. (Johnson, 1994, p. 748)

In addition, compositions belonging to the minimalist style generally contain simple harmonies, often diatonic pitch collections, and slow harmonic rhythms. Importantly, the melodic attributes of the minimalist style do *not* include extensive melodic lines. Rather, the style is characterised by short, repetitive melodic patterns. Above all, the minimalist style is characterised by repetitive rhythmic patterns, whose "organisation, combination, and individual shapes provide the primary points of interest in the style" (Johnson, 1994, p. 748).

According to this definition, many pieces by La Monte Young, which focus on long held tones, are not representative of the minimalist style (for example *For Brass*, 1957). Similarly, Reich's *Four Organs* (1970), which is based on the gradual augmentation of individual notes within a single chord, is characteristic of the aesthetic, but not the style.

Conversely, other compositions are characteristic of the style, but represent a departure from the original aesthetic. For example, the texture of Reich's *Music for 18 Musicians* (1976), consists of small repetitive rhythms, with very slight changes in surface detail. However, the composition departs from the aesthetic, in the sense that it also "employs goal directed motion, particularly in its harmonic changes and formal scheme..." (Johnson, 1994, p. 749).

Several of Reich's later works, such as *Music for Large Ensemble* (1978), *Octet* (1979), *The Desert Music* (1984), and *The Four Sections* (1987), do not represent all of the features of the minimalist style. For example, while repetitive rhythmic patterns, and interlocking structures are prominent in these works, they are coupled with longer and more ornate melodic lines, and often supported by long sustained tones.

According to the definition of minimalism as a 'technique', proposed by Glen Watkins (1988), minimalism exhibits a "general reduction of materials and emphasis on repetitive schemes and stasis" (p. 572). In this sense, certain features of compositions such as *The Desert Music*, *The Four Sections*, and *Different Trains* can be identified as minimalist, despite the fact that some features of the style are retained, and others rejected. For example, while more extensive melodies appear in *The Desert Music* (for example, measure 117), these melodies become the subject of "repetitive schemes and stasis", through extreme overlapping and fragmentation.

> If minimalism is defined only as an aesthetic, then just a few pieces meet the narrow qualifications of minimal music. Likewise, if minimalism is defined purely as a style, then this style period was remarkably short and has already ended, since few, if any pieces after the 1970's exhibit all the characteristics of the style. (Johnson, 1994, p. 750)

Therefore, the term minimalist technique can be applied on a much broader basis, to describe participating forces in Reich's more recent compositions, rather than being restricted to describing insular, self-contained structures. The development of minimalism can be viewed as a natural progression from its early experimental beginnings (as aesthetic) to its more recent interactive role. The effect of combining the minimalist technique with progressive features and external symbolism is explicit in *Different Trains*, where Reich "establishes the illusion of the sonorous envelope through a texture that suggests both an internal, oceanic immersion in repetitive fragments of sound, *and* an obsessive, external, and iconic representation of trains (Schwarz, 1993, p. 40).[25] Similarly, while elements of representation and subjective feeling are introduced in other compositions, such as *The Desert Music* and *The Four Sections,* the minimalist technique is employed to return these elements to their non-representative states, through deconstruction and destabilisation.

By viewing minimalism as a technique, some important distinctions between Reich's music, and other composers of the 'style' can be made. This distinction lies in the capacity for Reich's music to generate unexpected patterns, through tenuous relationships between musical events. This can be contrasted with other examples of minimal music, in which the resulting percept is equivalent to the temporal order of events. For these reasons, Reich's music, both early and late, can be discussed with reference to more recent compositional developments, especially music which is

[25] Italics in original. For a discussion of the "sonorous envelope", see Chapter 2.

concerned with "how our perceptual ordering faculties react when attempting to make sense of borderline states" (Ferneyhough, 1994, p. 115).

The 'New Complexity'

The analytical paradigm for musical time, introduced in Chapter 2, was used to investigate both objective and subjective approaches to pattern structure and temporality in Reich's music (see Figure 2-1). I have argued that critical information about musical time can be revealed by considering points of similarity and divergence between these different perspectives. In particular, I am referring to the extent to which different analytical perspectives agree or disagree on issues of musical directionality, that is, linear and non-linear characteristics of musical time. I have demonstrated that a multifaceted approach to temporality in Reich's phase shifting music reveals a considerable amount of divergence between inherent and perceived structures. Similarly, the minimalist 'technique' in Reich's later works, which is combined with more expansive melodies and goal-directed features, presents the listener with "incompatible fields of meaning" which arise from "simultaneously fighting and reinforcing directionality" (Boros, 1994, p. 94). In this section, different temporal forces in music, which can be viewed according to the proposed analytical paradigm, are discussed in relation to musical complexity.

In scientific terms, complexity can be defined as a "new way of thinking about the *collective* behaviour of many basic but interacting units" (Coveney & Highfield, 1995, p. 7). The interaction of these units "lead to coherent collective phenomena, so-called emergent properties that can be described only at higher levels than those of the individual units" (p. 7). While there is still a considerable amount of contention regarding the definition of the 'New Complexity' in music, the levels on which they agree tend to reflect scientific definitions of the term such as that offered by Coveney and Highfield above. For example,

> The consensus thus far seems to be that the level of complexity in a given musical instance does not necessarily correspond to the *amount* of information presented, but has more to do with contextual relationships, and with the quality of mental structures derived from the surface by the

> listener. (Boros, 1994, p. 91)

Therefore, the 'new' complexity in music refers not to the density of musical material, or to the level of dexterity required in performance, but to the capacity of music to generate emergent properties, which represent the "collective behaviour" of basic interacting units. In Reich's phase shifting music, these properties are the 'resulting patterns' or 'psycho-acoustic by-products' which emerge from interlocking structures, played on identical instruments. The fact that these patterns may emerge with or without the listener's volition, is indicative of a structural system which challenges perceptual thresholds. It follows that in order to identify such a system, analysis must consider levels of divergence between inherent and perceived structures.

In the case of Reich's phase shifting music, emergent properties appear in prolongation regions where there is no structural change in the music. Similarly, the very gradual transitions which take place in acceleration regions, have the capacity to generate sudden perceptual shifts. Such shifts are characteristic of nonlinear systems, in the sense that "nonlinearity causes small changes on one level of organisation to produce large effects at the same or different levels" (Coveney & Highfield, 1995, p. 9). In relation to his own music, Brian Ferneyhough (1994) suggests that the capacity for music to yield complex results relates to an imbalance between "containing frame" and "component details":

> My own interests have gravitated towards how our perceptual ordering faculties react when attempting to make sense of borderline states - that is, situations in which an apparent disbalance between implied scale of observed system and actual apportionment of confirming or disconfirming subsystems, conspires to create zones of instability in which linear modes of cataloguing incoming stimuli are suspended in favour of sudden leaps, fractures, or twists of focus. (Ferneyhough in conversation with Boros, 1994, p. 115)

Therefore, unlike most stylistic conventions, which strive for "large-scale equilibrium between containing frame and degree of permitted deviation of component details..."

(p. 115), complex music is characterised by a high degree of uncertainty regarding the "implied scale" of the relationship between frame and detail. As suggested by Ferneyhough (1994), the uncertainty of this relationship is due, in part, to high levels of "self-referentiality and embedding procedures" (p. 115). The musical analysis of Reich's phase shifting music presented in Chapter 4, revealed high levels of equivalence, inclusion and complement relations. Similarly, many of Reich's later works, in which patterns are replicated at close rhythmic transpositions (for example, *The Desert Music*, measure 117), demonstrate high levels of self-referentiality.

In section one of the chapter, I argued that Reich's later works demonstrate an increasing tendency to 'freeze the play' of the system. That is, certain features of the music are clearly distinguished from the rest of the texture, and as a result, these features retain their 'identity' on repeated listenings. However, such features are combined with highly repetitive interlocking textures, which continue to offer multiple viewpoints, and maintain a high degree of ambiguity with regard to identity. In contemporary music, the idea of identity and permanence has been challenged, in particular, by composers such as Cage, Feldman, Wolff and Brown. That is, by employing techniques such as graphic notation, indeterminacy, and improvisation, these composers relinquished control over their music to a certain degree, by allowing freedom in performance which extended beyond interpretation. However, in Reich's phase shifting music and many of his more recent works, the variable identity of the musical work relates to perceptual thresholds, and the tenuous relationship between musical parameters. Once again, this idea concurs with current interpretations of complex music:

> Music that is perceived as complex seems to actively encourage the coexistence, both within a single hearing and amongst different hearings, of multiple viewpoints, implying a high degree of ambiguity with regard to its "true identity" as seen in terms of susceptibility to the imposition of perspective bound hierarchies. (Boros, 1994, p. 91)

The ambiguous nature of Reich's phase shifting music has been discussed and tested, in this research, in terms of van Noorden's fission and segregation boundaries, and the principles of auditory streaming. While the parameters that potentially influence stream segregation are many, the most influential in Reich's music are pitch proximity, tempo, and timbre. These conditions create a texture which is susceptible to either coherence or segregation, falling within van Noorden's (1975) "ambiguous region". The "resultant patterns" in Reich's music, which are highlighted through instrumental doubling, draw attention to the unstable nature of the musical texture. That is, we become aware that the texture is a source of many different patterns, some of which require 'pointing out', and others which can be isolated clearly. In listening to this music, we become aware of the limits of perception, particularly when patterns which were once held in awareness become irretrievable. In Chapter 2, I defined the space that both produces and dissolves resulting patterns as the "inter-text". Similarly, with regard to complex music, Boros draws attention to the "in-between-ness" of musical relationships:

> As time goes on, my attention is increasingly drawn to the tenuous, unstable relationships between these fleeting sonic phantoms, to the fluttering and flickering of the auditory lens caused by their innate "in-between-ness" and by their necessarily complex behaviour. (Boros, 1994, p. 94)

In several of Reich's later compositions, repetitive pulses and the tight interlocking of instrumental parts have the potential to absorb the linear movement which might otherwise be implied by harmonic change and dynamic variation. For example, in the opening section of *The Desert Music* (see Figure 7-5), the fading in and out of expansive chords in the voices, strings and winds (the pitch combinations of which change every 4 or 5 bars), creates the impression that they are emanating from the existing interlocking structure. That is, by illuminating something that is embedded within the pre-existing texture, the effect is one of stasis rather than forward movement. In relation to his composition *Mnemosyne*, Ferneyhough comments on how extreme "vertical" relationships have the potential to force the mind in on small structural details, obscuring the active passage through time which is traditionally associated with music listening:

> As the piece goes on, the linear dimension is progressively imprisoned, its impetus absorbed by an even tighter lattice of vertical reference pitches. The more insistent the presence of harmony as passive obstacle, the more the mind begins to focus in on time in terms of momentary degrees of resistance rather than spaces within which time naturally unfolds. The more claustrophobic this situation becomes, the more temporal flow manifests itself as physical substance rather than a relational frame of reference within which materials are sequentially disposed. (Ferneyhough in conversation with Boros, 1994, p. 23)

Similarly, in several of Reich's more recent works, "claustrophobic" situations arise when a relatively discrete melody is deconstructed and layered to the point of saturation. In these situations, the density of musical material, which evolves from a single sequential melody to a static succession of chords, significantly alters the perception of time. For example, in *The Desert Music*, the distinctness of the cello and violin melody at measure 117 is gradually replaced by ambiguous reflections of itself. Gradually, the level of echoing and fragmentation builds to a point of melodic saturation.

While Reich's compositional development demonstrates some significant transitions, such as the introduction of new rhythmic techniques, and the gradual expansion of musical resources (such as harmony and orchestration), continuity is a significant feature of all his music on some level. Despite the increase in harmonic movement in later works, this movement is still slow in comparison with other contemporaneous works. Reich's extensive use of continuous structures could be viewed as a lasting interest in perceptual ambiguity. As suggested by Ferneyhough in relation to complex music, continuity is a pre-requisite for perceptual shifts, and unexpected patterns:

> It's true that my music happens to highlight insistently some of the more unstable and seemingly arbitrary facets of current compositional thinking: that necessarily follows from what happens to interest me, which is the expressive potential of ambiguous and volatile states. It would be a mistake, though, I

> feel, to assume that "continuity" on some level or other is not a pre-requisite of my approach - no fracture or twist can be perceived *per se* unless it is a fracture or twist *of something*, at least one of whose constituent defining qualities or fundamental assumptions is understood as providing a referential constant. (Ferneyhough in conversation with Boros, 1994, p. 129)

Further parallels between Reich's music, and the music of the so-called 'New Complexity', relate to the blurring of conventional foreground and background relationships. The lack of differentiation in Reich's music between melody and accompaniment, particularly in earlier works, creates a decentralised system where 'unprivileged' patterns alternate between figure and ground. With regard to complex music, Boros states:

> Traditional notions of "foreground" and "background", of "primary" and "secondary" material, are often called into question or made moot, requiring the conscientious listener to come to terms with the tenuousness of this music's very existence, and permitting us to participate directly in the creative act via the process of formulating our own interpretational strategy "on the fly", given the absence of ready-made handholds. (Boros, 1994, p. 91)

The "absence of ready-made handholds" is characteristic of much of Reich's music, which allows the relationship between musical events to 'speak for themselves'. Therefore, despite elements which generate a level of expectancy in Reich's music, such as the gradual augmentation of voices and organs in *Music for Mallet Instruments* (1973), the simultaneous activity of repetitive interlocking patterns threatens to "undermine whatever narrative continuity may exist" (Boros, 1994, p. 95).

The similarities between Reich's music, and the music which has recently been interpreted as constituting the 'New Complexity', are clearly independent of style. Importantly however, they highlight a broader movement in contemporary music, which is characterised by a shift away from "linear acoustic models, separable and independent parameters of aural perception, and stimulus-response behavioural models towards a recognition of the role of nonlinearity, multidimensional percepts, and information processing" (Truax, 1994, p. 178). I have argued that by defining minimalism as a 'technique', aspects of Reich's music which extend beyond the characteristics of the minimalist 'style' can be more easily recognised. In addition, I have demonstrated that these similarities are revealed by a multifaceted approach to temporality, which is capable of revealing opposing temporal forces, and the ability for continuous repetitive structures to generate relatively complex and unexpected results.

Chapter 8

Overview, Conclusions and Recommendations

This chapter begins with a summary of Chapters 1 to 7, followed by the conclusions of the study and recommendations for future research.

Overview of the Dissertation

The principal aim of this study was to investigate how pattern participates in the perception and cognition of Reich's phase shifting compositions. The lack of attention to Reich's music in the literature was considered to be a result of the timeless nature of his music, which is commonly viewed as conflicting with the aims of music theory. I have suggested that a comprehensive understanding of Reich's music is limited by this problem. In response, the approach adopted in this research supplemented formal musical analysis with principles derived from auditory perception research, to contribute to a more complete understanding of pattern perception and temporality in Reich's music, and to a contextualisation of his work. Importantly, this research set out to contribute to a meaningful understanding of Reich's music, which goes beyond providing perceptual evidence for what is already known intuitively by musicians and composers. The interdisciplinary approach required confronting and resolving a range of methodological questions related to the application of perception research to relatively complex musical stimuli.

The literature reviewed in Chapter 1 of the dissertation demonstrated a relatively limited body of research on Reich's music. As stated, one of the problems which has hindered past research is the fact that Reich's early music tends to resist conventional analysis. This problem is not only relevant to Reich's music, but to a large and significant body of contemporary music which is concerned with ateleology rather than linear, goal-directed structures. Similarly, conventional analysis does not accommodate the high degree of perceptual ambiguity associated with Reich's early music. In contrast, principles derived from auditory perception research provide a platform from which to investigate the extent of this ambiguity, and consequently, how the experience of this music might differ between different listenings, and among different listeners. The question of how listeners extract patterns from more complicated auditory mixtures is central to the experience of Reich's phase shifting music. Chapter 1 outlined a number of interdisciplinary considerations regarding the application of perception research to musical examples. Of primary concern among musicologists, is the tendency for perception experiments to isolate single musical parameters, and to thereby compromise the overall context of the music by extrapolating brief fragments for investigation. I argued that the absence of linear structures, the high degree of repetition and focus on the 'perceptual present' in Reich's phase shifting works, minimises many of the problems commonly associated with music perception experiments.

Chapter 2 introduced a paradigm for the study of musical time which encompassed four perspectives: formal, analytical, experiential and empirical. The paradigm was implemented in this study as a foundation from which to explore relationships between linear and non-linear characteristics of Reich's music. In order to provide a background to the study, Chapter 2 considered the philosophic and musical factors which influence how time is felt to pass.

Chapter 3 reported a literature review of auditory stream segregation to generate hypotheses for Experiments 2A and 2B. The first section reviewed studies which have examined the segregation of simple, repetitive musical sequences. These studies investigated a range of factors which influence the segregation of streams, including frequency proximity, pattern rate, spatial location, trajectory, frequency glides, timbre, loudness, and the cumulative effect. The second section of the review focused on the techniques that have been used by researchers for measuring the strength of segregation in auditory patterns. These techniques included direct and indirect measures. Direct measures are seen as obtaining a direct report of the experience of stream segregation, while indirect measures obtain an index of stream segregation through some other related phenomena. While direct measures are commonly used for examining the segregation of simple two or three tone auditory sequences (non-musical stimuli), they are generally inappropriate for measuring stream segregation in more complex music. In particular, direct measures require the listener to perform tasks which are generally less compatible with the experience of music listening, and were shown to be unsuitable for measuring streaming in complex musical sequences which have the potential to segregate in a variety of different ways. The evaluation of literature concerned with indirect measures determined that the pattern recognition task was the most suitable measure for exploring the role of stream segregation, and the salience of resulting patterns, in Reich's music.

The third section of the review outlined studies which have addressed the relationship between primitive and schema-based segregation processes. Although influences such as familiarity and attention have been explored with regard to stream segregation, prior research has not considered the extent to which a knowledge of musical structure influences listeners' ability to isolate patterns. Consequently, the experiments reported in Chapter 6 collected responses from both musicians and non-musicians in order to consider the influence of musical training and knowledge on listeners' ability to isolate resulting patterns in Reich's *Piano Phase*. The final section of the survey outlined the few studies which have explored the role of stream segregation in musical examples. Generally, these studies provided perceptual evidence for well known musical concepts, and focused on examples from the Western music repertoire which have been rigorously examined by music theorists over many years. By contrast, the purpose of utilising perception research in this study, was to compensate for the lack of information on Reich's music. Previous research on stream segregation suggested that the phase shifting music was suitable for experimental investigation due to its largely unvarying parameters, and its highly repetitive nature.

Chapter 4 presented an analysis of three of Reich's phase shifting compositions to consider evidence for linear structures, and the extent to which these structures influence the listener's experience of time. The analysis focused on the beat-class sets which arise from the combination of the principal patterns with their duplicates at different rhythmic transpositions. The overall design of attack-point frequencies revealed progressive structures in *Phase Patterns*, and in one of the principal sets of

Violin Phase. Conversely, the analysis revealed that the principal sets in *Piano Phase* and several primary beat-class sets in *Violin Phase* do not demonstrate a steady progression toward a foreseeable goal. Importantly, the lack of variation in the structural design of attack-point frequencies contributes to an explanation of why Reich's phase shifting music is commonly described as evoking a sense of timelessness or stasis. The final part of Chapter 4 presented a theoretical evaluation of the role of stream segregation in Reich's phase shifting compositions. This evaluation suggested that the parameters of Reich's phase shifting music, in combination with the specific instructions for performance, ensure that a range of resulting patterns will occur with or without the listener's volition. The ambiguity of resulting patterns was demonstrated by mapping the pitch and tempo parameters of the phase shifting music onto van Noorden's (1975) temporal coherence and segregation boundaries. The analysis of cellular patterns suggested that the complexity of vertical structures in the music, created by the simultaneous activity of interlocking structures, has the capacity to hinder the perceptual salience of the progressive structures revealed in the musical analysis. Once again, this contributes to an explanation of why Reich's phase shifting music is commonly described as suspending musical time.

Chapter 5 presented two experiments which investigated the perception of pulse in Reich's *Piano Phase*. A primary purpose of the experiments was to consider the relationship between the listener's perception of pulse, and regularities in pattern structure. In Reich's *Piano Phase,* the majority of patterns can be heard in groups of four or groups of six. This is due to the fact that individual pitch streams in each region evoke conflicting pulse trains. Consequently, the listener's perception of pulse is influenced by which of the available patterns is held in awareness. This phenomenon was assumed to contribute to the sudden perceptual shifts which occur in Reich's phase shifting music. Prior to the experiments, a pilot study was conducted to test certain aspects of the experimental design and procedure. The results of the pilot, and previous research evidence, confirmed the validity of the method which was used to record data in the main experiments.

Experiment 1A tested listeners' perception of pulse in *Piano Phase*. Following Parncutt (1994), the number of times subjects chose a particular pulse-train was taken as a measure of its perceptual salience. The results indicated that pulse perception in this music is relatively ambiguous. Generally, the results were consistent with existing models of pulse perception. For example, in accord with Parncutt (1994), pulses tended to gravitate toward moderate tempo, and listeners' responses reflect a process by which sound onsets are mapped against the elements of an isochronous template. Experiment 1B measured the salience of pulse sensations for high and low resulting patterns (individual streams). The most commonly selected pulse trains for high and low patterns were compared with the results of Experiment 1A. The results supported the assumption that listeners' experience of pulse is dependent, to a large extent, on which of the resulting patterns is held in awareness. That is, the segregation of streams has an important bearing on listeners' perception of pulse in this music.

Chapter 6 reported two experiments which tested the perceptual salience of resulting patterns in *Piano Phase*. Experiment 2A required listeners to rate the clarity of isolation of high and low target patterns in prolongation regions. In Experiment 2B, targets consisted of the rhythmic component of the patterns only, to consider the influence of rhythmic regularity on the formation of streams. Both experiments tested musicians and non-musicians to assess the influence of musical experience on the segregation of patterns. The results of the experiments demonstrated that the salience of resulting patterns is not consistent throughout prolongation regions. This finding suggested that the salience of progressive features associated with attack-point design (demonstrated in Chapter 4) is hindered by the variable strength of segregation in each region of the music. The results also showed that prior musical experience did not significantly enhance listeners' ability to isolate target patterns. This finding supports the notion that the role of musical schemas in the perception of Reich's phase shifting music is relatively limited.

Chapter 7 demonstrated that certain perceptual features of Reich's phase shifting works remain strong temporal forces in his compositions after 1971. An analysis of several of Reich's later works was used to argue that current definitions of minimalism are limited in their scope. The term minimalist 'technique', which implies a reduction of musical materials and emphasis on repetition and stasis, was supported by the analysis. In particular, the term minimalist technique allows aspects of minimalism to be identified in later compositional developments of the aesthetic or style. The final section of the chapter addressed recent definitions of the "New Complexity". The discussion drew parallels between Reich's compositions, and the music of more recent composers whose interest lies in emphasising the perceptual ambiguity of musical relationships.

Conclusions and Recommendations

The conclusions and recommendations of the study are divided into implications for auditory and music perception research and implications for music theory.

Implications for music and auditory perception research

As stated in the introduction to the thesis, while the primary aim of the research was to contribute to a better understanding of Reich's music, the research simultaneously tested the application of certain theories in auditory perception, and their ability to shed light on the perception of relatively complex music.

Prior to this research, the principles of auditory stream segregation had not been examined experimentally in the context of authentic musical examples drawn from the repertoire. The literature survey presented in Chapter 3 suggested that the pattern recognition task was the most appropriate measure of stream segregation in Reich's phase shifting music. Importantly, the essence of the scene analysis process is that it separates patterns from one another (Bregman, 1990). Consequently, listeners were asked to rate the clarity of isolation of resulting patterns in Reich's *Piano Phase* to determine the relative salience of patterns which lie within the musical texture.

The results of the experiments (2A and 2B) suggested that the salience of resulting patterns (based on primary beat-class sets) vary significantly between the prolongation regions of *Piano Phase*. The salience of patterns was considered to be an important determinant of temporality in this music, because the perception of broader structural characteristics (for example, the design of attack-point frequency) is dependent on the perception of patterns at the microstructural level. This research demonstrated that the principles of auditory stream segregation have the potential to inform an understanding of how pattern perception on one level of music can influence the perception of overarching musical structures.

In addition, the results of Experiments 2A and 2B demonstrated that the ability to isolate resulting patterns in Reich's *Piano Phase* was not significantly influenced by the musical knowledge and experience of subjects. This finding is important because it provides a basis for understanding the role of schemas in the perception of Reich's music. In the perception literature, the role of musical knowledge and attention are often grouped together as a means of distinguishing them from primitive processes of organisation (Bregman, 1990). However, by demonstrating that musical knowledge and experience does not appear to influence the clarity of patterns in *Piano Phase*, the role of attention-based processes can be discussed separately. For example, despite the fact that listeners in Experiments 2A and 2B were told which patterns to listen for, that is, to direct their attention in a particular way, patterns in some prolongation regions were significantly more difficult to isolate than others. This suggests the presence of some primitive, automatic process of organisation which reduces the salience of resulting patterns, despite the influence of attentional processes. Therefore, although there are many possible resulting patterns available in Reich's phase shifting music, primitive processes of organisation allow some patterns to be heard more easily than others.

A further implication of the study relates to Jones' rhythmic theory of attention (1981), which states that the perceptual integration of a series of tones is based on the capacity of the attentional process to predict the position of the next tone. That is, her theory assumes that randomly ordered sequences of tones do not form coherent streams. This would suggest that the acceleration regions in Reich's phase shifting music, which contain chaotic rhythmic characteristics, would not segregate into high and low auditory streams. Although this aspect of the music was not tested experimentally in the present research, I suggest that despite the chaotic rhythmic and melodic activity in these regions, the music still has a tendency to be grouped into high and low auditory streams. This would support Bregman's (1990) suggestion that the anticipation of future events is not a necessary factor in the formation of auditory streams, because listeners are capable of forming coherent streams from irregular sounds in the environment.

The subjects tested in experiments 2A and 2B were restricted to Western listeners only. The influence of culture on listeners' ability to segregate auditory patterns is a relatively untouched area of research, however researchers have acknowledged that the schema-based segregation skills of different individuals should show strong differences (Bregman, 1990). In terms of primitive segregation processes, Bregman has stated that he has "no knowledge of studies of the application of Gestalt ideas on an intercultural level, although [he] would expect the perception of all humans to be governed by these principles" (Wegner, 1993, p. 231). The findings of the exploratory study reported in Appendix A, which tested Western and non-Western listeners, raised some important questions regarding the influence of culture on listeners' ability to segregate auditory patterns. The results of this study suggested that cross-cultural research may provide an important insight into the complex relationship between primitive and schema-based processes of organsiation.

The experimental inquiry conducted in this study also has implications for research which is concerned with generating models of pulse perception. Experiments 1A and 1B, reported in Chapter 5, tested listeners' perception of pulse in Reich's *Piano Phase*. The results of the experiments were examined in relation to findings by Parncutt (1994), who tested listeners' perception of pulse in six rhythmic patterns of varying complexity. Although the stimuli used in Parncutt's experiment did not contain a melodic dimension, several important aspects of his conclusions were found to be consistent with the results of Experiments 1A and 1B reported in the present research.

For example, pulses tended to gravitate toward moderate tempo (600-700 ms) regardless of pattern rate, and listeners' responses generally reflected a process by which sound onsets are mapped against the elements of an isochronous template. This last point is also consistent with studies by Lerdahl and Jackendoff (1983), Longuet-Higgins and Lee (1984) and Povel & Essens (1985). While the results of

Experiments 1A and 1B tended to support Parncutt's existence region of pulse sensation (200-1800 ms), there were several exceptions. According to Parncutt (1994), these results may be explained as a phenomenon related to musical form rather than rhythm, however further research would be necessary to explore this discrepancy further.

In summary, the results of Experiments 1A and 1B suggest that existing theories of pulse perception, in particular, the model of pulse salience proposed by Parncutt (1994), is capable of predicting certain aspects of pulse perception in more complex stimuli such as the music investigated in this study. However, further research is needed to assess the extent of this application.

Implications for Music Theory

The main purpose of this study was to contribute to a better understanding of temporality in Reich's music by investigating how pattern participates in the perception and cognition of his compositions. My thesis was that the temporal experience of Reich's music is significantly influenced by how a listener's perceptual ordering faculties respond to the ambiguous pattern structures which characterise much of his music.

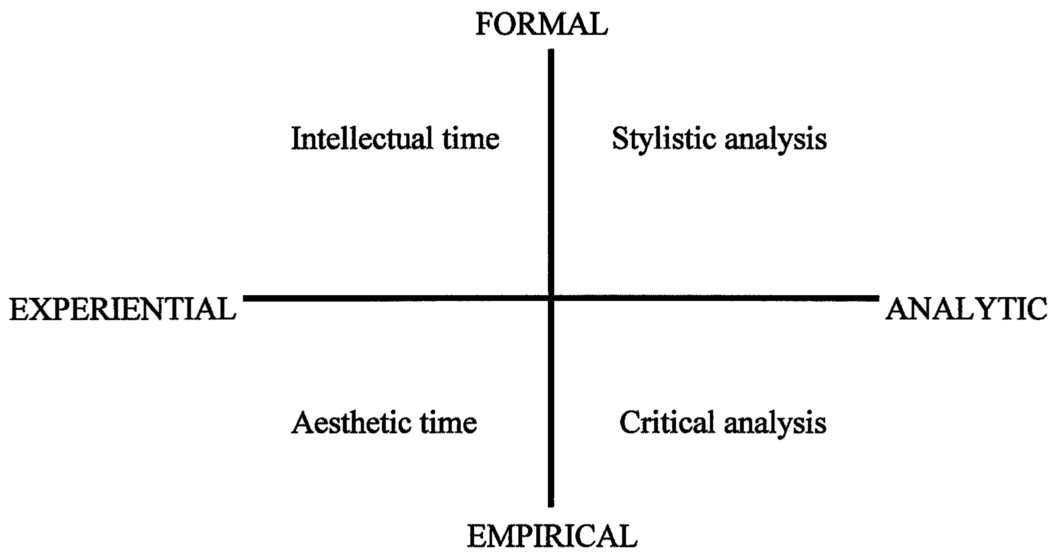
The ambiguous nature of resulting patterns in Reich's phase shifting music draws attention to the concept of musical identity. In order to understand the notion of variable identity in Reich's music, this research examined the perception of patterns in terms of the principles of auditory stream segregation. While contemporary composers have challenged the notion of musical identity by introducing elements of freedom in performance, Reich's phase shifting music allows no improvisation whatsoever (Reich, 1974). Rather, the variable identity of these works can be understood in terms of perceptual thresholds, the tenuous relationship between musical parameters, and the ability of listeners to actively select patterns from within the musical texture.

The investigation of perceptual processes in this study showed that listeners' ability to isolate resulting patterns was not significantly enhanced by musical knowledge and musical experience (Experiments 2A and 2B). That is, non-musicians were able to isolate resulting patterns as effectively as musicians. This finding reinforces the idea that Reich's phase shifting music is relatively free of the type of goal-directed structures which musical schemas respond. Consequently, in contrast to music which is based on intricate hierarchical structures, the musically untrained listener is not disadvantaged in terms of their ability to perceive resulting patterns in the music. For these reasons, the results of this study provide valuable information toward a more systematic explanation of why Reich's music has proven to be popular among the broader listening population, rather than being restricted to a musically elite audience.

The multifaceted approach to temporality adopted in this study was based on the analytical paradigm shown in Figure 8-1. The paradigm was used to demonstrate that the elusive nature of musical time can be better understood by acknowledging several analytical perspectives which include both objective and subjective approaches. In particular, it provided a basis for investigating the question of why certain music, which appears to be organised to engender motion, often results in a sense of apparent stasis.

Figure 8-1 Analytical paradigm for musical time

Source: Barry, 1990, p. 84



For example, the musical analysis of Reich's phase shifting music presented in Chapter 4 revealed structures which appeared to be organised to produce a sense of forward motion. Specifically, the analysis showed that the design of attack-point frequencies in *Phase Patterns* and the set [0257] in *Violin Phase* contain progressive structures which imply goal direction. These findings led Cohn (1992) to suggest that Reich's phase shifting music reflects a traditional nuanced approach to composition, and that the design of attack points should have a direct impact on the listening experience.

The perceptual analysis of Reich's phase shifting music presented in Chapter 6 explored the relative salience of resulting patterns, in an attempt to understand why the music is commonly described as evoking a sense of stasis, despite the presence of underlying progressive structures. The perceptual analysis demonstrated that the salience of resulting patterns varied considerably throughout prolongation regions. This finding leads to the conclusion that the perception of broader structures, generated by attack-point design, may be hindered by the relative salience of resulting patterns within and between prolongation regions.

In summary, the perception of resulting patterns in Reich's phase shifting music, that is, the way listeners order events in time, ultimately defines the influence of broader overarching structures on the listener's temporal experience. By supplementing conventional musical analysis with research from auditory perception, this research has provided a better understanding of the complex interaction of elements which are responsible for shaping the temporal experience.

While I have argued that approaching analysis from one perspective (Figure 8-1) is informative in its own right, I suggest that critical information about the nature of musical time can be revealed by considering the relationship between different perspectives. For example, this study demonstrated that different analytical approaches may provide opposing viewpoints, however, when considered together these viewpoints provide a better understanding of the complexities of musical time.

In particular, I suggest that opposing viewpoints are more likely to emerge in the analysis of nonteleological music.

While the analysis of nonlinear or vertical music is commonly restricted to description (Kramer, 1988), this study demonstrated that a consideration of different analytical perspectives has the potential to inform an understanding of the relationship between linear and nonlinear characteristics of musical time. Therefore, the results of this study strongly support a multifaceted approach to the study of musical temporality such as that proposed by Kramer (1988) and Barry (1990).

There are several implications for musical analysis that arise from the present study. Importantly, most analytical studies of music are based on techniques that have been developed and refined over many years, and as a result, these studies provide valuable insights into the understanding and meaning of music. However, as many contemporary composers continue to abandon traditional notions of musical time in favour of more nonlinear systems of organsiation, it is possible that new approaches to analysis, such as the one adopted in this thesis, may be necessary to understand the nature of nonteleological music more completely. Importantly, interdisciplinary research has the capacity to inspire new and complementary directions in the analysis of music, which in turn, broaden our understanding of the complexities of musical time.

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Glossary of Terms and Abbreviations

Italicised terms indicate separate glossary entries.

acceleration region

Regions in Reich's phase shifting music where one player gradually accelerates the tempo of a pattern, ahead of the other player, until they have moved one beat ahead in the cycle. These regions connect *prolongation regions*.

ANOVA — Analysis of variance.

ateleology — In application to music, the term implies non goal-directed motion.

auditory scene analysis

The process which allows listeners to recognise the source of incoming auditory stimuli in the environment such as speech and music.

auditory stream segregation

The segregation of an auditory sequence into two or more individual pitch streams.

bc set — *beat class set.*

beat class set — Indicates the rhythmic dispersion of notes in numerical terms. Numbers in the set denote the position of each tone in the pattern cycle.

cellular pattern — See *resultant pattern.*

canon — Two or more identical melodies sounded at different rhythmic transpositions.

cognition — The act or process of knowing.

coherence — When two or more tones are perceived as emanating from the same sound source. This applies either to tones in succession, or simultaneously occurring sounds.

coherence boundary

The point at which a listener can no longer hear an alternating pitch sequence as a single auditory stream.

contour — Shape or outline.

complex tone — A sound with energy emitted at several frequencies simultaneously.

cumulative effect

The strengthening of stream segregation over time. That is, the longer a listener is exposed to a streaming sequence, the more difficulty they will have hearing the sequence as a single coherent stream.

deconstruction — The philosophical notion advocated by Jacques Derrida which relates to the process of subverting the central term in language, to reveal alternative interpretations of meaning.

deep scale property

A set holds the deep scale property if its *interval classes* are distributed such that each dyad class (pair) is represented with a unique multiplicity (Cohn, 1992).

deviation — The distance (in *ms*) between sound events and subjects responses in Experiments 1A and 1B.

direct measure — Measures the process of stream segregation directly. For example, if the listener's task is to indicate the number of streams they hear, this is a direct measure.

doubled attack — A doubled attack indicates that two notes of the same stream are sounded on the same rhythmic beat in the cycle.

existence region of pulse sensation

As defined by Parncutt (1994), the region in which the distance between pulse sensations falls between 200 ms and 1600 ms.

figure/ground reversal

The alternation of two percepts, where figure refers to the pattern held in awareness, and ground refers to the pattern not held in awareness. Each pattern may act as a figure or a ground.

fission — The separation of an alternating sequence into two or more individual pitch streams.

fission boundary — The point at which an alternating pitch sequence can no longer be heard as segregated.

FM tone — Frequency-modulated tone.

Gestalt — A movement in Psychology, originating in Germany, where principles are described which explain the human tendency to perceive well organised wholes even when the source being perceived consists of separate, disjointed or isolated parts.

IOI — inter-onset interval

ic — *interval class*

indirect measure

A method which examines the role of stream segregation via some related phenomena. For example, asking subjects to judge the temporal order of tones in a sequence may be used as an indirect measure of stream segregation.

inter-onset interval

The temporal distance between the offset on one sound event, and the onset of another event directly proceeding it.

intertext — The space in between two or more available percepts which cause patterns to emerge and disappear.

interval class — Obtained by subtracting the number of attack-points in a cycle from the total number of beats per cycle. If interval classes are distributed with a unique multiplicity, they hold the *deep scale property*.

isochronous template

Defined by two pieces of information, that is, *period (P)* and *phase (Q)* (Parncutt, 1994).

linear music — Refers to music which invokes a sense of forward motion. That is, it contains related events or sections over time.

Max 3.5 — The interactive music software application which was used to develop the computer programs which controlled all experiments reported in the thesis.

MR — Modulation rate.

ms — Milliseconds.

nonlinear music — Refers to music which does not invoke a sense of forward movement and avoids a goal-directed relationship between successive events.

null hypothesis — A statistical assertion that there is no real difference between two or more groups or populations along a particular parameter of interest.

P — *Period*

p — The probability of being wrong if rejecting the *null hypothesis*. For example, a *p* value of 0.01 means that the null hypothesis will be incorrectly rejected one in 100 times, on average. Also referred to as the *significance* of a test.

pc set — *pitch-class set.*

perceptual decomposition of *complex tones*

A complex spectrum is decomposed when a sequential grouping process captures components out of it (Bregman, 1990).

period — The interval of time between two consecutive pulse sensations.

phase — The time at which pulse sensations occur relative to some referent time (Parncutt, 1994).

phase shifting — The process of gradually moving one pattern ahead of another, until the first player has moved one beat ahead of the second.

pitch-class set — Numerical representation of a series of pitches, indicating their intervallic relationship.

primitive segregation

A pre-attentive process which partitions an auditory sequence into two or more separate pitch streams.

prolongation region

The non-*accelerating regions* of Reich's phase shifting compositions Each region contains the principal pattern, combined with a rhythmic transposition of the same pattern (in *canon*).

pulse salience — The perceptual significance, strength or prominence of a pulse sensation (Parncutt, 1994).

pulse-train A series of pulse sensations.

Q *Phase*.

reliability The ability of a psychological instrument to measure responses consistently.

resulting pattern

The patterns perceived by the listener in Reich's phase shifting music, either selectively or involuntarily.

resultant pattern

Patterns in Reich's phase shifting compositions which are accentuated through instrumental doubling. Also referred to in the thesis as *cellular patterns*.

RI *Retrograde inverse*.

schema Refers to a "control system in the human brain that is sensitive to some frequently occurring pattern" (Bregman, 1990, p. 401).

sequential grouping

The perceptual grouping of tones occurring in succession.

SD Standard deviation.

significance See *p*.

spectral grouping

The perceptual grouping of simultaneously occurring sound events.

SPSS Statistics Package for the Social Sciences.

stasis Used to describe music which appears stationary or fixed rather than forward moving. That is, *ateleological*.

stream segregation

The process which segregates an auditory pattern into two or more discrete pitch streams.

tactus An underlying beat or pulse.

teleology In application to music, the term implies goal-direction.

temporal coherence boundary

The point at which an alternating pitch sequence can no longer be heard as a single coherent stream.

TINV *Transpositionally invariant.*

trajectory The *contour* or direction of a sequence of tones.

transpositionally invariant

Refers to a beat-class set that is capable of mapping at some non-zero transposition (Cohn, 1992).

trill threshold The boundary between two percepts: coherent and segregated.

validity In reference to a psychological instrument, the ability of that instrument to measure what it claims to measure.

Appendices

Appendix A: Cross-Cultural Comparative Study of Resulting Patterns in Reich's *Piano Phase*

Cross-Cultural Comparative Study of Resulting Patterns in Reich's *Piano Phase*

Introduction

The comparative study reported in this Appendix tested the salience of resulting patterns in Reich's *Piano Phase* for Western and non-Western listeners. That is, the pattern recognition method used in Experiments 2A and 2B (Chapter 6), and by Tougas and Bregman (1985), was adapted for a cross-cultural comparison of pattern salience. Western listeners consisted of 18 Australian musicians with a high level of exposure to Western art music and Western popular music. Non-Western subjects comprised 18 people from Erromango, a southern island of Vanuatu. The Erromangan participants were remote villagers with no prior exposure to Western Art Music, and minimal exposure to Western popular music. The two subject groups responded to identical stimuli, and followed the same experimental procedure.

This study questions the generality of the findings that researchers have obtained regarding the thresholds of stream segregation and the ability of listeners to isolate patterns within a melodic context. As stated in Chapter 3, there are no studies reported in the literature, to date, which have explored the influence of culture on the segregation of auditory streams. As stated by Bregman, "I have no knowledge of studies of the application of Gestalt ideas on an intercultural level, although I would expect the perception of all humans to be governed by these principles" (Wegner, 1993, p. 231).

The question that formed the basis of the experimental investigation reported here was: *Do non-Western listeners perceive the same resulting patterns as Western listeners in Reich's Piano Phase, and if so, how salient are they?* The question could be expressed as: To what extent does culture influence listener's ability to segregate auditory streams in a musical context. Although this question is immense in its scope, the exploratory study reported here raises some important questions regarding the potential of cross cultural comparative research in this area, in addition to raising some important methodological considerations.

Aim

The two primary aims of the experiment were:

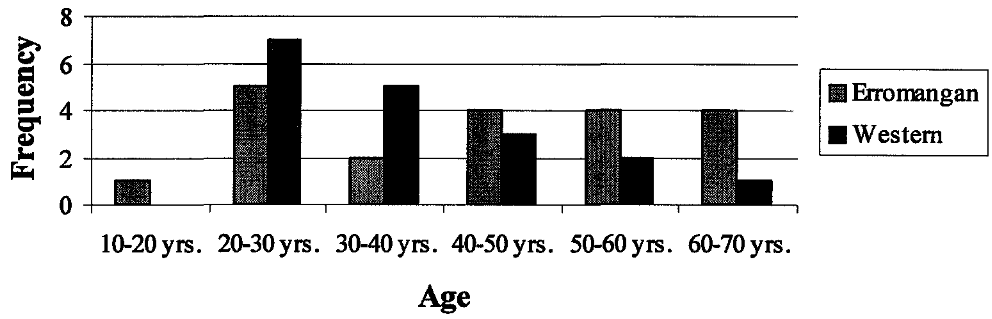
1. to see if the resulting patterns in Reich's *Piano Phase* were the same or different for Western and non-Western listeners, and if so,
2. to measure the salience of resulting patterns in the music for the two groups.

Methodology

Subjects

36 subjects participated in the experiment. The sample comprised 18 Western listeners and 18 Erromangan listeners. The distribution of age according to subject group is shown in Figure 1.

Figure 1 Distribution of subjects according to age: Western and Erromangan listeners



<u>Western listeners</u>

Western listeners comprised 11 females and 7 males. All subjects had played at least one Western musical instrument for a minimum of 5 years (mean 7.2 years). All Western listeners reported having normal hearing. Fourteen of the subjects had been formally trained in music, and four were self-taught musicians. No subjects in the group were familiar with the music of Vanuatu.

<u>Erromangan listeners</u>

Erromangan listeners consisted of 10 males and 8 females. The participants who volunteered for the experiment came from several different villages distributed along the southern extent of the island, from Dillon's Bay to South River. The majority of subjects in the group played some ukulele, and in keeping with cultural traditions all subjects sang on a regular basis. Although there were several radios on the island, participants spent most of their time listening to local music, and music from the surrounding islands in the South Pacific. Without easy access to batteries however, radio listening tended to be fairly sporadic. Of the 18 subjects, 12 were tested in a small classroom in a village which was located in the center of several smaller surrounding villages. The remaining six subjects were tested in their home villages.

Unlike many of the other islands in Vanuatu, Erromango is not a common destination for Western tourists. On the contrary, many of the people on the island have had very little or no exposure to Westerners. One of the participants, who assisted in the organisation of the field research, acted as an interpreter for the remainder of subjects in the group (see *Procedure*). The participants generally communicated in the local Erromangan language, however all subjects spoke Bislama, the national language of Vanuatu.

Questionnaire

A questionnaire was completed by all participants prior to the experiment. The questions were designed to collect information regarding participants exposure to Western and non-Western music, and to establish levels of practical musical experience. The questions asked to the Erromangan group were:

1. Can you play a musical instrument? If so, how long have you been playing for?
2. What types of songs do you play or sing? Do you play or sing styles of music other than Church songs eg. traditional music or Western music?
3. Do you listen to Western music? If so, how often.

These questions were asked to participants by the local field work assistant, who then translated the responses to the researcher in English. The survey showed that the Erromangan participants over the age of 40 (12 of the 18 subjects in the group) reported that they had never listened to Western music. Participants in younger age groups reported listening to popular Western music (from Australia and New Zealand) on the radio sometimes. The same participants also listened to music from

Africa, Papua New Guinea, the Solomon Islands, Fiji, Samoa and New Caledonia. The instruments played by Erromangan participants included guitar and ukulele. Only 3 subjects in the group (all over the age of 40) had learnt traditional custom music. All participants sang church songs and hymns on a regular basis. Five subjects in the group played in a local string band.

The survey for the Western group included the following questions:

1. Can you play a musical instrument? If so, how long have you been playing for?
2. What styles of music do you play or sing?
3. Do you listen to non-Western music? If so, how often.

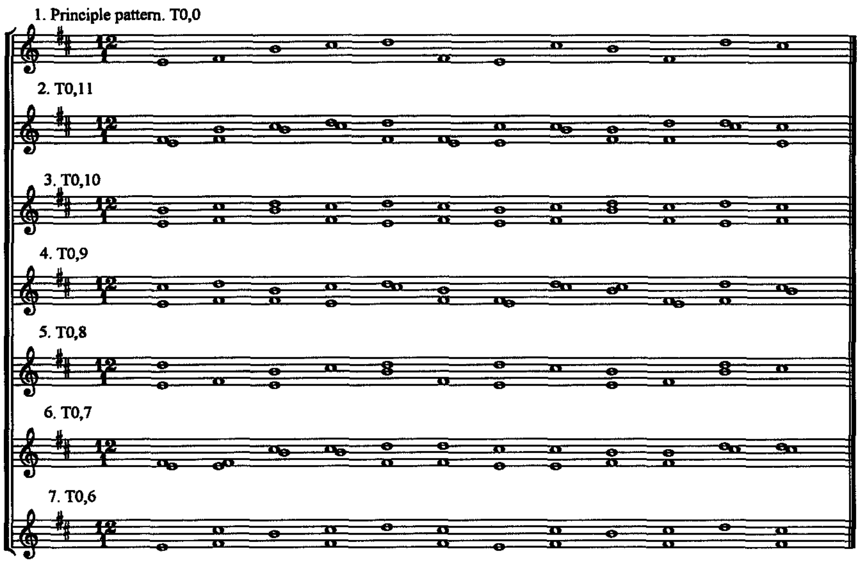
All subjects in the Western group had played at least one musical instrument (including voice) for a minimum of 5 years. Fourteen subjects in the group played both Western classical music and popular music. The remaining four subjects played popular music only, and were not formally trained in music. All subjects in the group indicated that they listened to non-Western music "rarely" or "very little".

Stimuli

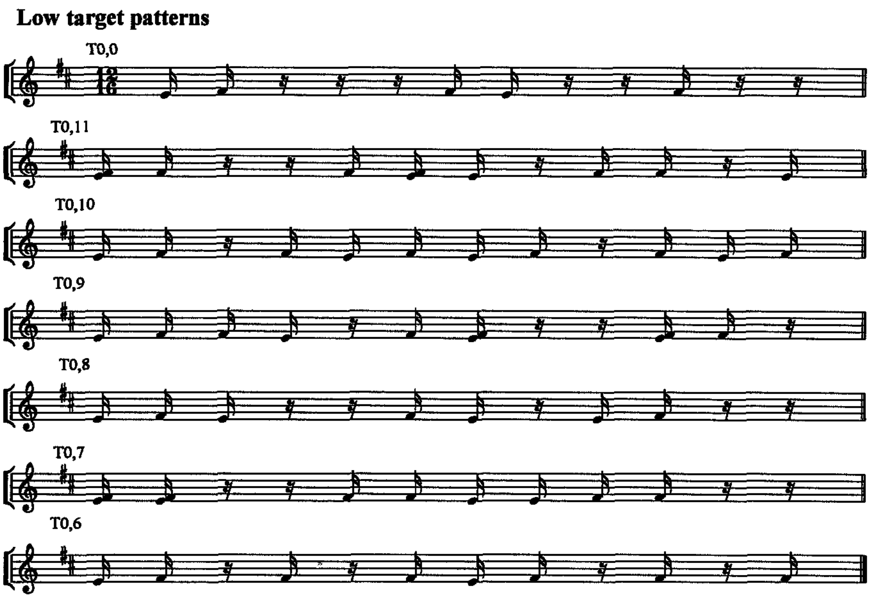
The stimulus patterns used in the experiment were divided into target and comparison patterns. Comparison patterns were the principal pattern (T0,0), and the first six prolongation regions {T0,11; T0,10; T0,9; T0,8; T0,7 and T0,6} of Reich's *Piano Phase* (see Figure 2).

Figure 2 Target and Comparison Patterns Used in the Experiment

Comparison patterns



High target patterns



As in Experiment 2A (reported in Chapter 6), the target patterns represented divisions of each phase into two sub-patterns: notes of the high stream (B, C#, and D) and notes of the low stream (E and F#). Therefore, each comparison pattern was associated with two target patterns. In each trial, comparison patterns proceeded target patterns after a 1.6 second silence. Once again, phases 7 to 11 (T0,5 - T0,1) of *Piano Phase* were not tested, because they contain the same structure as the first six phases (in a retrograde design). The only difference is that they begin on a different beat of the twelve beat cycle. Target and comparison pairs were presented at the presentation rate IOI = 139 ms (crotchet = 108).

Materials

It was important to ensure that the materials used in this study were not completely foreign to Erromangan listeners. The stimulus patterns for experiment 2A (see Chapter 6 for details of how patterns were created) were recorded onto magnetic tape, and played to subjects on a Sony Walkman portable cassette player (WM-GX322) through high quality Sony headphones. Figure 3 shows the rating scale used for Erromangan listeners, the only difference being that the numbers on the scale were written in Bislama, which was understood by all participants. The response sheet consisted of three scales for practice sequences, and a rating scale for each of the 14 trials in the experiment. Subjects were asked to circle or mark the number on the scale which indicated the clarity of the target pattern in each trial.

Figure 3 Rating Scale for Erromangan listeners (in Bislama)

The experiment was preceded by a short practice session, so that participants were clear about the task, and were comfortable with how to register their responses on the scale shown above.

Procedure

The experimental procedure was explained by the researcher to the field assistant, Jerry Taki, who had a broad understanding of the English language. The instructions were also explained by the researcher in Bislama for reinforcement. It was stressed that the following points must be translated carefully to each participant:

1. only circle number "7" on the rating scale if you can hear the target pattern very clearly in the comparison pattern, that is, with no distractions whatsoever from other notes in the sequence. If you rate number "7", this means that no effort was required to hear the target pattern.
2. your rating does not indicate whether or not you can remember the target pattern and sing it over the top of the comparison pattern in your head. Rather, your rating indicates how clearly the target pattern stands out in the comparison.
3. all ratings made on the response sheet are correct, therefore, the experiment is not a test or a competition. The task requires you to rate patterns in relation to each other, so try to use the scale as widely as possible.

These instructions were understood clearly by the field assistant, and repeated back to the researcher in English. He stated that these instructions would be successfully translated into the local Erromangan language. The field assistant had a written copy of these instructions, so that they could be carefully explained to each participant. The procedure outlined below was explained to each participant by the field worker prior to the experiment.

As mentioned, the majority of Erromangan subjects carried out the experiment in a school classroom, and participants were tested one at a time. A practice session, conducted prior to the experiment, consisted of three demonstration trials, and three practice trials, to allow the subject to become familiar with the task, and to promote consistent use of the rating scale. Subjects were told that on each trial, they would be presented with a pair of sequences, that is, a 'target' sequence followed by a 'comparison' sequence. They were told that the comparison sequence was composed of the target sequence mixed together with other surrounding tones. In each trial, the subjects heard four continuous repetitions of the target pattern, a 1.6 second silence, then four repetitions of the comparison pattern. The ability of a coherent auditory stream to be heard as an entity that is perceptually isolated from the surrounding sounds was used as an index of stream formation. At the end of each trial, subjects were asked to rate how clearly isolated the target pattern was, when heard as part of the comparison sequence. Responses were made on a seven-point rating scale. The endpoint (1) of the rating scale was labeled 'very clearly not isolated', meaning that the standard sequence could not be heard at all within the comparison sequence. The other endpoint (7) was labeled 'very clearly isolated'. The end-points and numbers on the rating scale were written in Bislama on the response form for Erromangan participants. Subjects were told that if they were to rate the target pattern 'very clearly isolated', they should be able to isolate the pattern without *any* effort. The subjects understood that the target sequence was always present in the comparison sequence, but that it would not always be easy to isolate.

The target and comparison pairs were presented to subjects in one of three orders (recorded on three separate cassette tapes). To minimise learning effects, the order of trials were constructed to eliminate the possibility of the same comparison pattern being presented in consecutive trials. The researcher and field assistant sat inside the room during each session, away from the participant, and were available for help if necessary. Each participant took approximately 20 minutes to complete the questionnaire, a short practice session, and the main experiment. After completing the experiment, participants were encouraged to express any problems they encountered during the experiment, and to offer any general comments regarding the music they just heard.

Results

The results below show the responses given by Western and Erromangan listeners in each of the fourteen trials, and the mean scores and standard deviation for both groups.

Table 1 Results for High Target Patterns

WL = Western listeners

EL = Erromangan listeners

Subject	T0,0		T0,11		T0,10		T0,9		T0,8		T0,7		T0,6	
	WL	EL	WL	EL	WL	EL	WL	EL	WL	EL	WL	EL	WL	EL
1	7	7	7	7	6	7	6	7	5	7	6	7	7	7
2	4	7	5	7	7	7	7	7	6	6	6	7	5	7
3	7	7	4	7	7	7	2	6	5	7	6	4	4	6
4	6	7	5	7	5	7	3	6	4	7	5	7	5	7
5	6	7	5	7	7	7	2	7	2	7	7	7	5	7
6	5	7	4	7	5	7	3	7	4	7	6	7	6	7
7	4	7	6	7	7	7	1	7	5	7	6	7	7	7
8	7	7	7	7	7	7	7	7	7	7	7	7	6	7
9	2	7	3	7	6	7	3	7	6	3	3	7	2	5
10	5	7	2	7	2	7	4	7	3	7	5	7	3	7
11	4	7	3	7	6	7	5	7	3	7	7	7	5	7
12	3	7	5	7	3	7	3	7	5	7	4	7	5	7
13	4	7	3	7	2	7	2	7	4	7	4	7	1	7
14	3	7	3	7	6	7	4	6	3	7	5	7	7	7
15	7	7	4	7	4	7	5	6	4	7	7	7	6	7
16	7	7	6	7	6	7	5	6	6	7	7	5	6	7
17	3	7	5	6	7	7	5	7	2	7	6	7	5	7
18	3	7	7	7	7	7	5	6	4	7	7	7	2	7
Mean	**4.83**	**7**	**4.67**	**6.94**	**5.56**	**7**	**4**	**6.67**	**4.33**	**6.73**	**5.78**	**6.72**	**4.83**	**6.83**
SD	**1.72**	**0**	**1.53**	**0.24**	**1.72**	**0**	**1.75**	**0.46**	**1.41**	**0.96**	**1.21**	**0.83**	**1.79**	**0.51**

The mean scores and standard deviations in Table 1 show that Erromangan listeners rated higher than Western listeners on average in each region. The lowest mean score for both groups occurred for the high pattern in T0,9. This result is consistent with the responses for Experiment 2A, which used the same stimulus patterns for Western musicians and non-musicians (see Chapter 6 results). Standard deviations indicate a high level of agreement among Erromangan listeners. All subjects in the Erromangan group rated "very clearly isolated" for the high patterns in regions T0,0 and T0,10. An analysis of variance with repeated measures revealed a significant main effect ($p<.05$) for the difference between the two subject groups.

Table 2 Results for Low Patterns

WL = Western listeners

EL = non-Western listeners

Ss	T0,0		T0,11		T0,10		T0,9		T0,8		T0,7		T0,6	
	WL	EL	WL	EL	WL	EL	WL	EL	WL	EL	WL	EL	WL	EL
1	5	7	5	7	5	7	6	7	4	7	6	7	7	7
2	4	7	4	7	4	7	6	7	6	6	5	7	4	7
3	6	7	5	7	2	7	4	7	3	6	3	6	3	7
4	6	7	5	7	3	7	4	7	1	7	2	7	6	7
5	4	7	3	7	2	7	3	7	3	7	1	7	6	7
6	1	7	4	7	5	7	3	7	1	7	6	7	5	7
7	7	7	3	7	2	7	7	7	6	7	7	7	5	7
8	7	7	7	7	2	7	7	7	7	7	7	7	7	7
9	5	7	3	7	2	5	6	7	5	7	6	2	4	6
10	1	7	1	7	4	7	5	7	3	7	3	7	2	7
11	5	7	2	7	1	7	2	7	2	7	1	7	1	7
12	7	7	3	7	5	7	3	7	3	7	6	7	5	7
13	6	7	6	7	4	7	6	7	5	7	6	7	7	7
14	1	7	6	7	3	7	5	7	4	7	4	7	3	7
15	7	7	4	7	2	7	6	7	4	7	4	7	7	7
16	5	7	6	7	3	7	7	7	3	7	5	7	5	7
17	4	7	2	7	4	7	2	7	3	7	4	7	2	7
18	7	7	7	7	7	7	7	6	7	5	7	7	7	7
Mean	**4.89**	**7**	**4.22**	**7**	**3.33**	**6.89**	**4.94**	**6.94**	**3.89**	**6.78**	**4.61**	**6.67**	**4.78**	**6.94**
SD	**2.08**	**0**	**1.77**	**0**	**1.53**	**0.47**	**1.76**	**0.24**	**1.81**	**0.55**	**1.97**	**1.19**	**1.96**	**0.24**

Table 2 shows that once again, the mean scores for Erromangan listeners are higher than the mean scores for Western listeners for all low patterns. Standard deviations indicate a high level of agreement for Erromangan listeners. In regions T0,0 and T0,11, all Erromangan participants indicated that the low target pattern was heard "very clearly isolated". Once again, an analysis of variance revealed a significant main effect ($p<.05$) for the difference between Western and Erromangan listeners.

Discussion

It must be considered whether or not some aspect of the methodology used in the study could account for the wide margin between mean scores for the two groups. Several methodological issues were re-examined in view of findings. For example, is it possible that the instructions for the experiment were not communicated successfully to Erromangan participants? Consequently, is it possible that participants misunderstood how to use the rating scale?

As explained in the procedure, several steps were incorporated to minimise problems associated with language barriers which have the potential to distort results. First, it was reinforced to subjects that a rating of "7" should only be given when the target pattern could be heard very clearly when mixed with the comparison. Despite this, the majority of subjects indicated a rating of "7" in almost every trial. After the experiment, participants were asked to explain why they did not frequently use the other numbers on the rating scale, and all subjects indicated that it was extremely easy to hear the target pattern in most trials. When asked why some patterns were given ratings less than "7" on the scale, all participants agreed that they were distracted by other notes; in the words of one participant, it was "something in the music" that made the target more difficult to hear. Finally, all participants understood prior to the experiment that low responses did not mean that they performed badly in the task. It was suggested to subjects that the target patterns would not always be easy to hear. Together, these factors suggest that the instructions were communicated successfully to Erromangan participants, and that they did understood how to use the rating scale.

There are several factors which might contribute to an explanation of the ability of Erromangan participants to isolate resulting patterns more clearly than Western participants. Bregman (1990) highlights an important issue regarding schema-based segregation processes:

> [Learning]...is based on the encounter of individuals with certain lawful patterns of their environments, speech and music being but two examples. Since different environments contain different language, musics, speakers...,

> the schema-based segregation skills of different individuals will come to have strong differences, although they may have certain things in common. (Bregman, 1990, p. 43)

As stated previously, Erromangan participants reported having very little exposure to Western popular music, and no exposure to Western Art Music. At the completion of the experiment, Erromangan participants were asked to describe what they thought the patterns in the experiment sounded like. Many participants indicated that the patterns sounded like "drums". More than half of the participants indicated that they listened to local and African drumming music on the radio fairly frequently. The influence of African music on Reich's music, discussed in the introduction to the thesis, suggests that listeners who have a high level of exposure to the complex rhythmic patterns of African drumming music may find resulting patterns easier to isolate than listeners who have had little or no exposure. For example, Jones' (1981) theory states that attention can be organised in a rhythmic manner. This means that when we listen to a pattern of sounds, the attentional process is capable of anticipating the position of the following sound on the time dimension. Importantly, predictable sequences allow their components to be caught in the net of attention, while unexpected elements may be lost (Bregman, 1990). According to this theory, if Erromangan participants had a higher level of exposure to the type of complex rhythmic patterns found in Reich's music, then this should increase their capacity to form coherent auditory streams. Much of the custom music of Vanuatu is based on the cyclic repetition of small phrases, which are susceptible to resulting patterns such as the type found in Reich's music.

A full interpretation of the results presented in this study, in terms of the influence of conditioning on listeners' ability to isolate resulting patterns, would require an in-depth study of the music of this region. At present, there are no available recordings of traditional or secular music on Erromango. More research would be necessary to develop and test hypotheses regarding the influence of musical, ecological and linguistic factors on the ability of participants to segregate auditory patterns. However, this study raises some important methodological issues, and suggests the potential for this type of comparative research to provide insights into the nature of auditory stream segregation. At the very least, it can be tentatively proposed that cultural determinants have an important bearing on listeners' ability to segregate patterns in Reich's music. The results of Experiments 2A and 2B (reported in Chapter 6) showed that listeners' ability to isolate resulting patterns in Reich's *Piano Phase* was not enhanced by a knowledge of the formal characteristics of Western music. That is, musicians were not significantly better than non-musicians at isolating resulting patterns. However, the study reported in this Appendix suggests that the ability for listeners to isolate resulting patterns may be influenced by the type of musical schemas relevant to a specific culture.

Appendix B: Scores for *Piano Phase, Phase Patterns and Violin Phase*

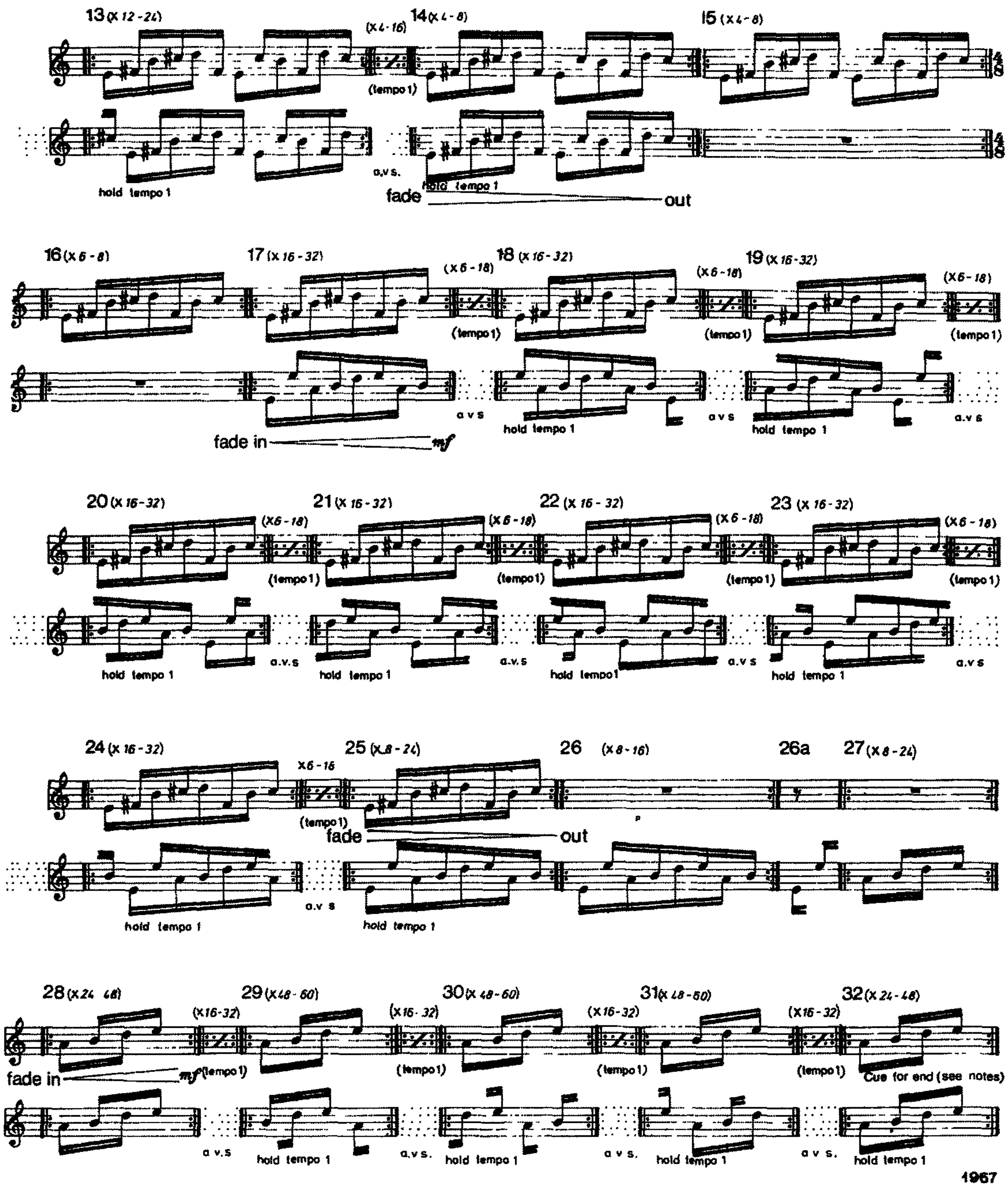
piano phase

for two pianos
or two marimbas*

steve reich

♩. = ca. 72

Repeat each bar approximately number of times written. / Jeder Takt soll approximativ wiederholt werden entsprechend der angegebenen Anzahl. / Répétez chaque mesure à peu près le nombre de fois indiqué.


13 (x 12-24)
(x 4-16)
14 (x 4-8)
15 (x 4-8)
(tempo 1)
hold tempo 1
a.v.s.
hold tempo 1
fade out
16 (x 6-8)
17 (x 16-32)
(x 6-18)
18 (x 16-32)
(x 6-18)
19 (x 16-32)
(x 6-18)
(tempo 1)
fade in mf
a v s
hold tempo 1
20 (x 16-32)
(x 6-18)
21 (x 16-32)
22 (x 16-32)
23 (x 16-32)
hold tempo 1
a.v.s
24 (x 16-32)
x 6-18
25 (x 8-24)
26 (x 8-16)
26a
27 (x 8-24)
(tempo 1)
fade out
p
a v s
hold tempo 1
28 (x 24 48)
(x 16-32)
29 (x 48-60)
(x 16-32)
30 (x 48-60)
(x 16-32)
31 (x 48-60)
(x 16-32)
32 (x 24-48)
fade in mf
(tempo 1)
Cue for end (see notes)
a v.s
hold tempo 1
1967


phase patterns
for four electric organs
steve reich
El organ 1
El organ 2
El organ 3
El organ 4
Complete resulting pattern of organs 1 and 2
alternate organ 3
alternate organ 4
fade in
1+2

9
10
11
12
1
2
(≈4-8)
fade out
fade in
ff
3
4
1+2
alternate 3
alternate 4
13
14
15
16

17
18
19
20
1
2
3
4
1+2
alternate 3
alternate 4
ff
(=4-8)
fade out
fade in
21
22
23
24
hold tempo !
(=8-16)
(=8-32)
accel. very slightly


25
26
27
28
1
2
hold tempo !
3
(≈ 4-8)
non legato
fade in
ff
4
1+2
alternate 3
alternate 4
29
30
31
32
fade out


33
34
35
36
1
2
3
4
1+2
alternate 3
alternate 4
(×4–8)
fade in
ff
fade out
37
38
39
40
(×8–16)


41
42
43
44
1
hold tempo 1
(×8–32)
2
accel very slightly
hold tempo 1
(×4–8)
(×4–8)
non legato
3
fade in
ff
(4–8)
non legato
4
fade in
1+2
alternate 3
alternate 4
45
46
47
48
1
2
(×4–8)
(×4–8)
(×4–8)
3
fade out
fade in
ff
(×4–8)
4
ff
1+2
alternate 3
alternate 4


49
50
51
52
(×4-8)
fade out
fade in
ff
1
2
3
4
1+2
alternate 3
alternate 4
53
54
55
56

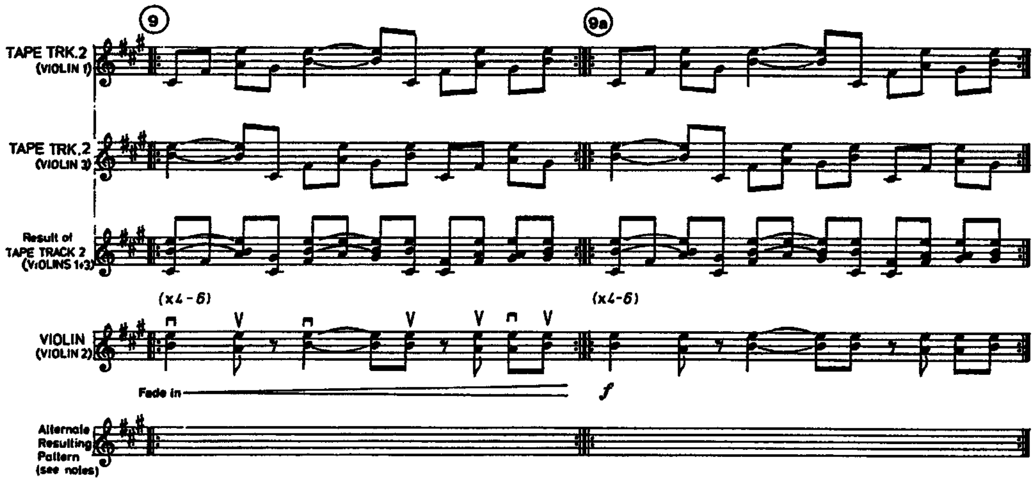

57
58
59
60
1
2
3
4
1+2
alternate 3
alternate 4
hold tempo 1
(×8-16)
(×8-32)
(×8-16)
accel. very slightly
hold tempo 1
(×4-8)
fade in
(×4-8)
fade in

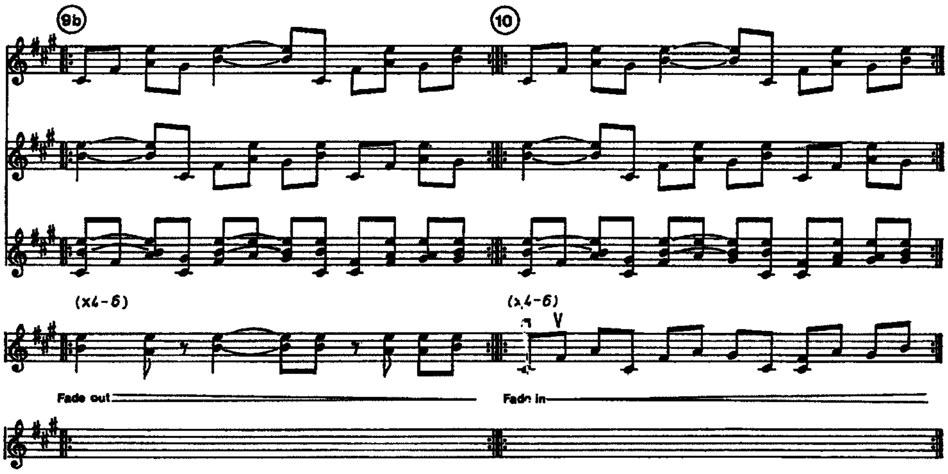

61
62
63
64
1
2
3
4
(×4-8)
(×4-8)
fade out
f
(×4-8)
(×4-8)
(×8-16)
fade out
f
f
f
×8-16

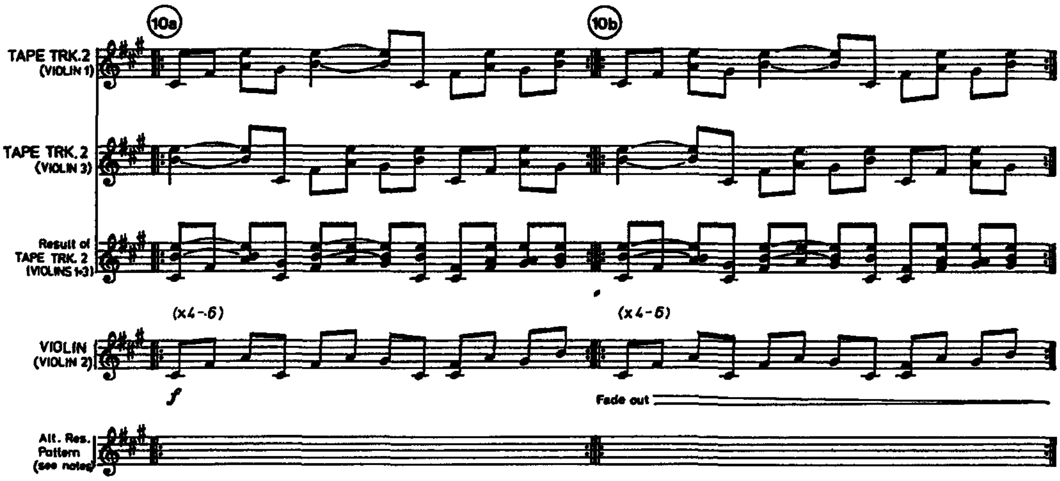

65
66
67
68
1
hold tempo 1
(≈8-32)
(≈16-32)
(≈8-32)
(≈16-32)
2
accel very slightly
hold tempo 1
accel very slightly
hold tempo 1
3
hold tempo 1
hold tempo 1
4
hold tempo 1
hold tempo 1


69
70
71
72
end 4 repeats after cue (see notes)
1
hold tempo 1
hold tempo 1
(≈8-32)
(≈16-32)
(≈8-32)
(≈16-32) end 4 repeats after cue (see notes)
2
accel very slightly
hold tempo 1
accel very slightly
hold tempo 1
end 4 repeats after cue (see notes)
3
hold tempo 1
hold tempo 1
end 4 repeats after cue (see notes)
4
hold tempo 1
hold tempo 1
attacca

C: *Violin Phase*


9
9a
TAPE TRK.2 (VIOLIN 1)
TAPE TRK.2 (VIOLIN 3)
Result of TAPE TRACK 2 (VIOLINS 1+3)
(x4-6)
(x4-6)
VIOLIN (VIOLIN 2)
Fade in
f
Alternate Resulting Pattern (see notes)


9b
10
(x4-6)
(x4-6)
Fade out
Fade in

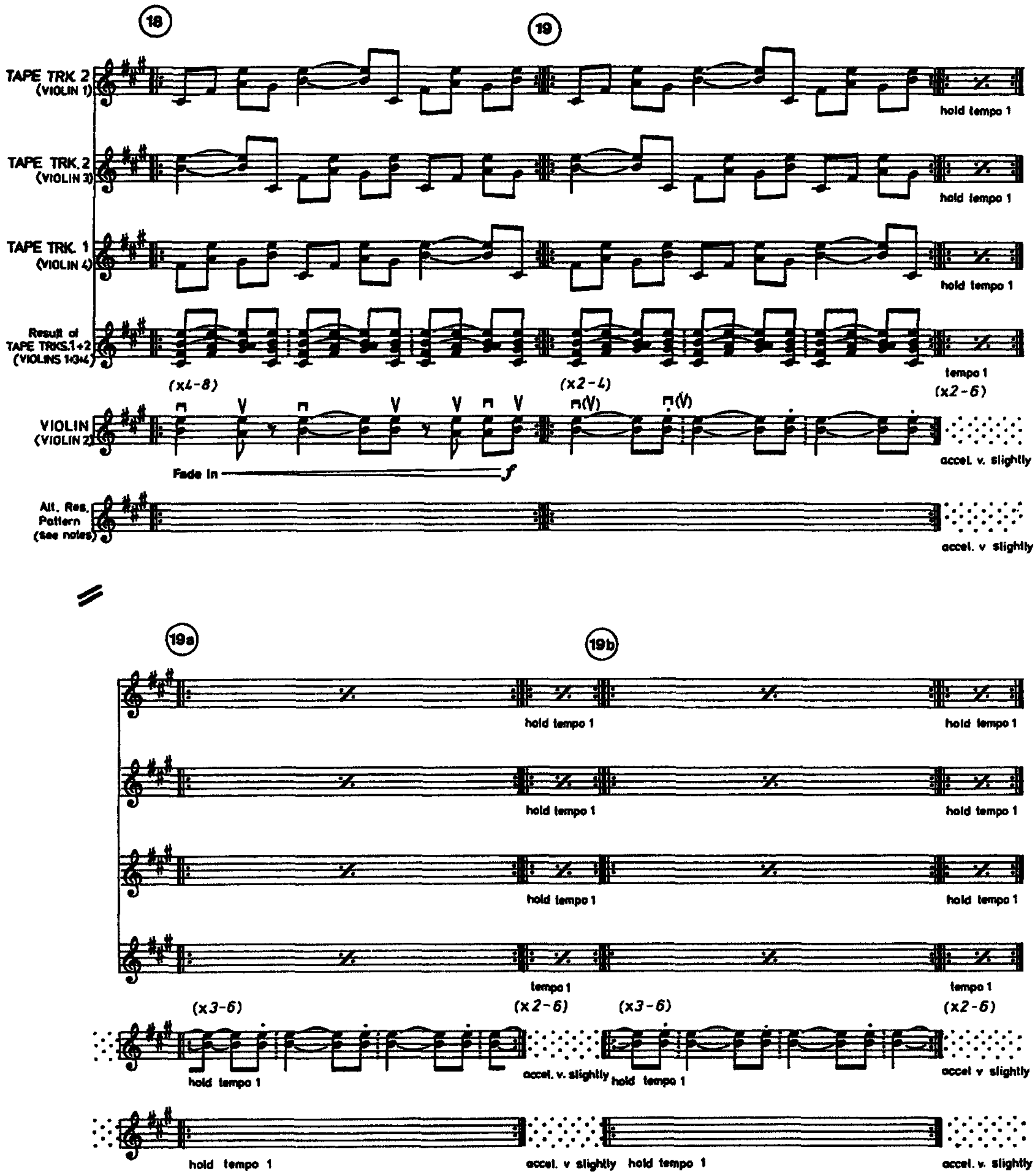

10a
10b
TAPE TRK.2 (VIOLIN 1)
TAPE TRK. 2 (VIOLIN 3)
Result of TAPE TRK. 2 (VIOLINS 1+3)
(x4-6)
(x4-6)
VIOLIN (VIOLIN 2)
f
Fade out
Alt. Res. Pattern (see notes)

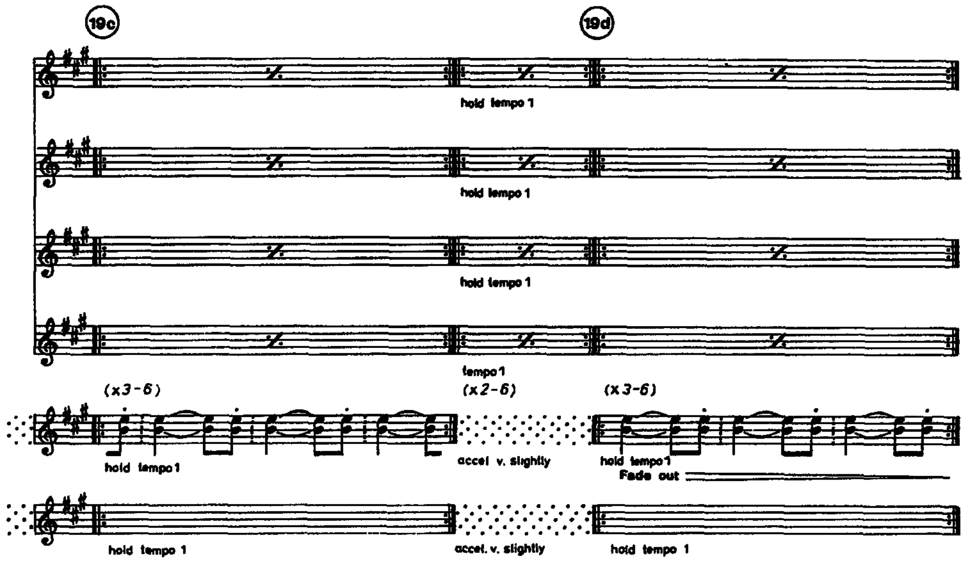

11
(x3-5)
Fade in

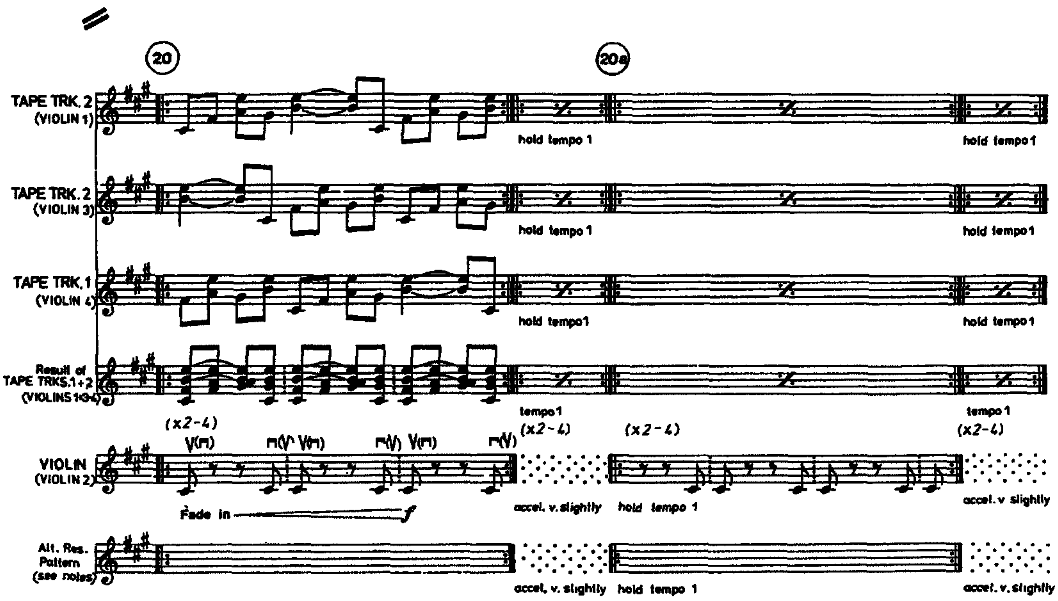

11a
TAPE TRK.2 (VIOLIN 1)
TAPE TRK.2 (VIOLIN 3)
Result of TAPE TRK.2 (VIOLINS 1+3)
(x3-5)
VIOLIN (VIOLIN 2)
f
Alt. Res. Pattern (see notes)

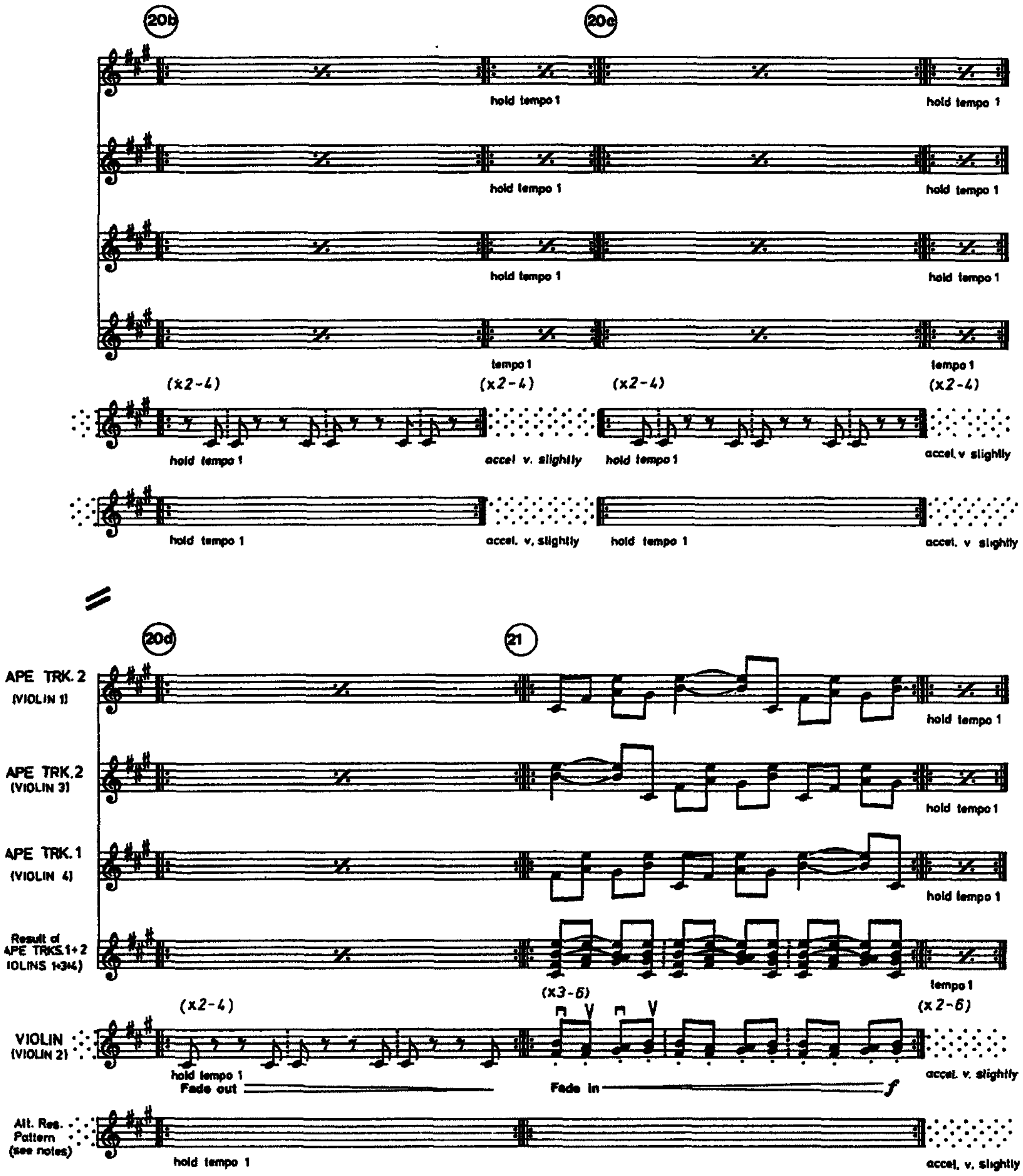

11b
(x3-6)
Fade out


12
13
TAPE TRK. 2 (VIOLIN 1)
hold tempo 1
hold tempo 1
TAPE TRK. 2 (VIOLIN 3)
hold tempo 1
hold tempo 1
(x8-12)
(x6-16)
(x8-16)
(x6-16)
VIOLIN (VIOLIN 2)
accel. v. slightly
hold tempo 1
accel. v. slightly
Fade in
mf
14
15
hold tempo 1
hold tempo 1
hold tempo 1
hold tempo 1
(x8-16)
(x6-16)
(x8-16)
(x6-16)
hold tempo 1
accel. v. slightly
hold tempo 1
16
17
TAPE TRACK 2 (VIOLIN 1)
TAPE TRACK 2 (VIOLIN 3)
(x4-8)
TAPE TRACK 1 (VIOLIN 2)
(x4-8)
Fade in
mf
(x4-8)
VIOLIN (VIOLIN 2)
hold tempo 1
Fade out

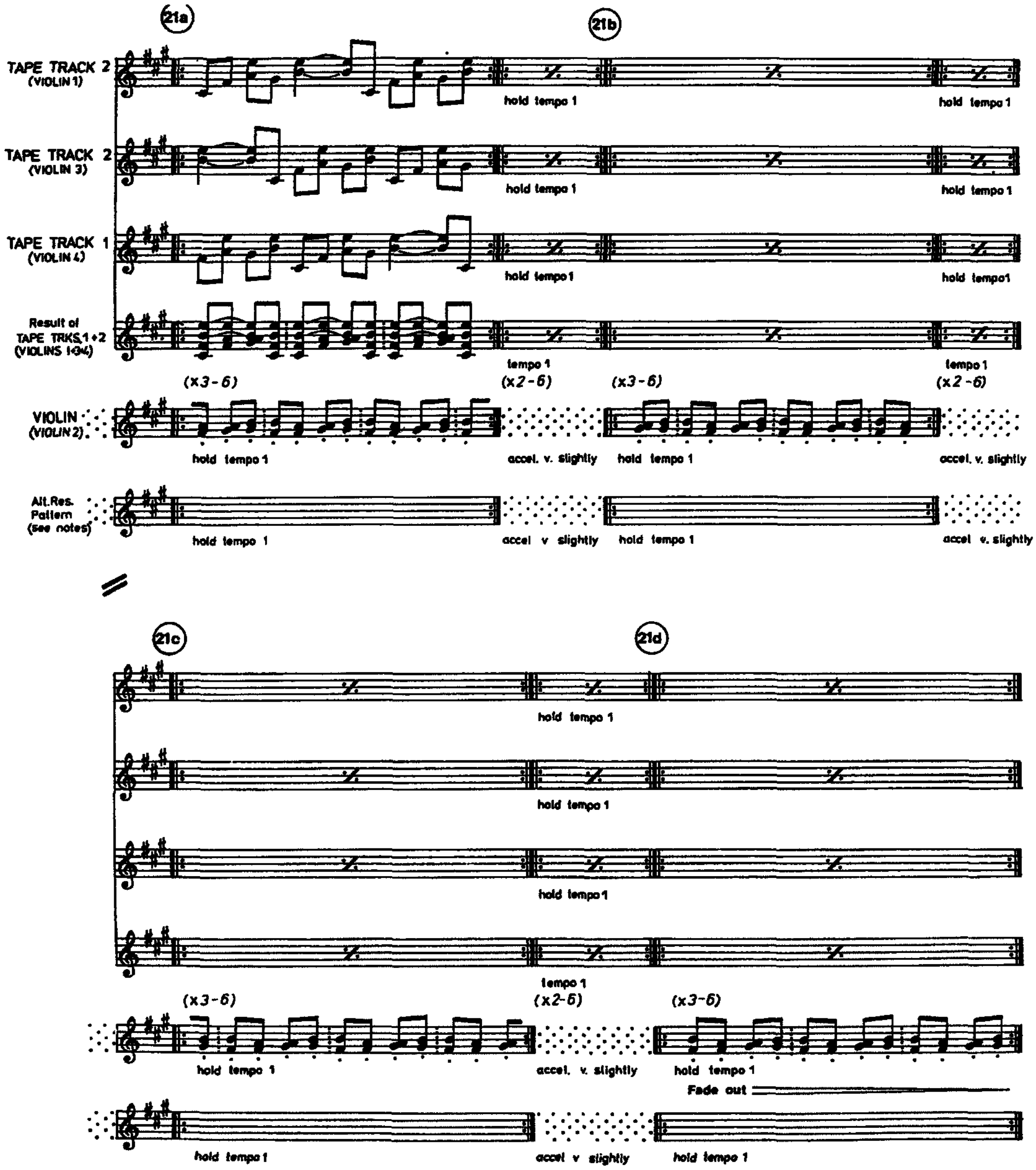

18
19
TAPE TRK. 2 (VIOLIN 1)
TAPE TRK. 2 (VIOLIN 3)
TAPE TRK. 1 (VIOLIN 4)
Result of TAPE TRKS.1+2 (VIOLINS 1+3+4)
VIOLIN (VIOLIN 2)
Alt. Res. Pattern (see notes)
hold tempo 1
tempo 1
(x4-8)
(x2-4)
(x2-6)
Fade in
f
accel. v. slightly
19a
19b
(x3-6)
(x2-6)
(x3-6)
(x2-6)
hold tempo 1
accel. v. slightly
tempo 1


19c
19d
hold tempo 1
hold tempo 1
hold tempo 1
tempo 1
(x3-6)
(x2-6)
(x3-6)
hold tempo 1
accel v. slightly
hold tempo 1
Fade out
hold tempo 1
accel. v. slightly
hold tempo 1

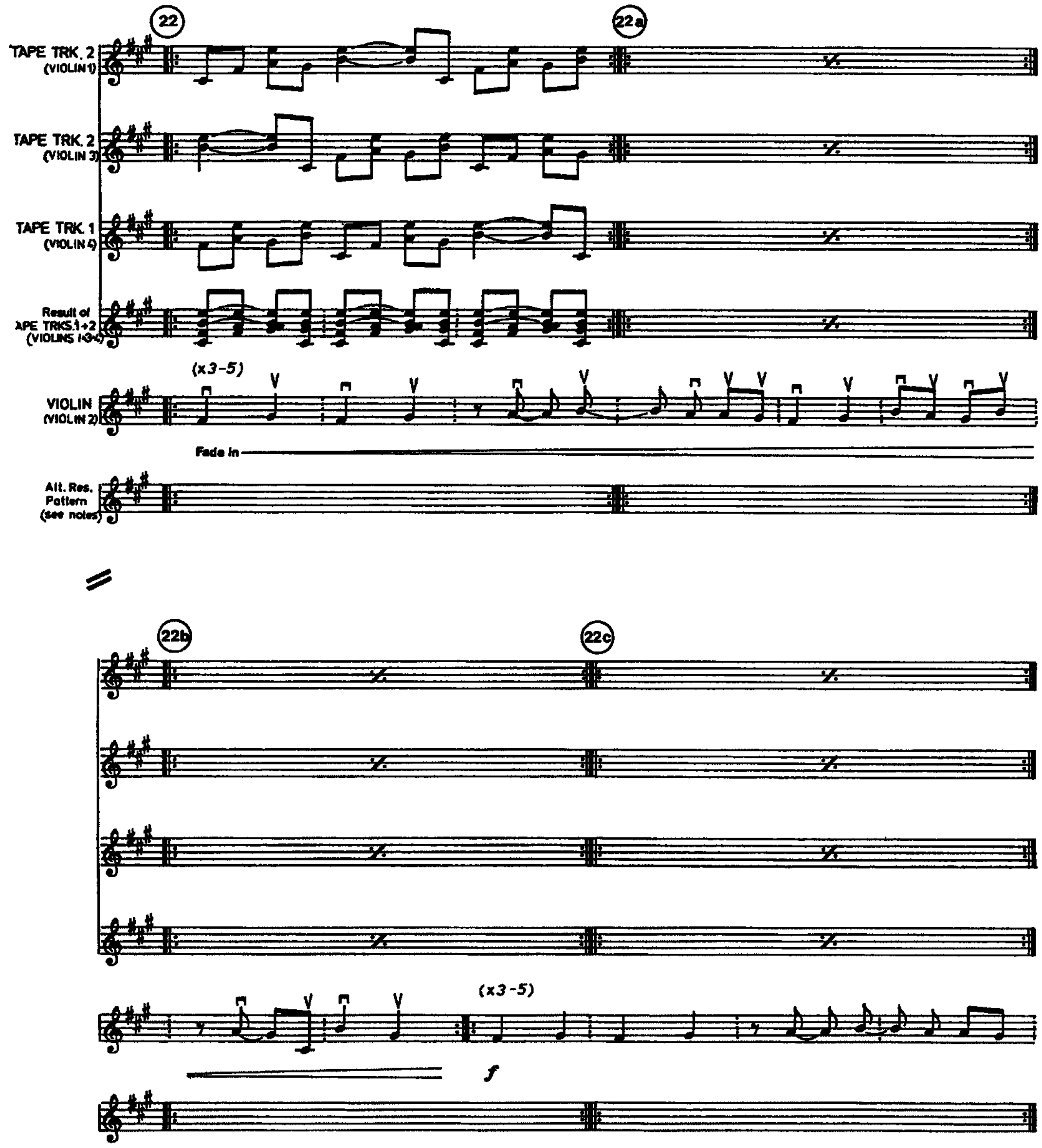

20
20a
TAPE TRK. 2 (VIOLIN 1)
hold tempo 1
hold tempo 1
TAPE TRK. 2 (VIOLIN 3)
hold tempo 1
hold tempo 1
TAPE TRK. 1 (VIOLIN 4)
hold tempo 1
hold tempo 1
Result of TAPE TRKS. 1+2 (VIOLINS 1-3-4)
tempo 1
tempo 1
(x2-4)
(x2-4)
(x2-4)
(x2-4)
VIOLIN (VIOLIN 2)
Fade in
f
accel. v. slightly
hold tempo 1
accel. v slightly
Alt. Res. Pattern (see notes)
accel. v. slightly
hold tempo 1
accel. v. slightly

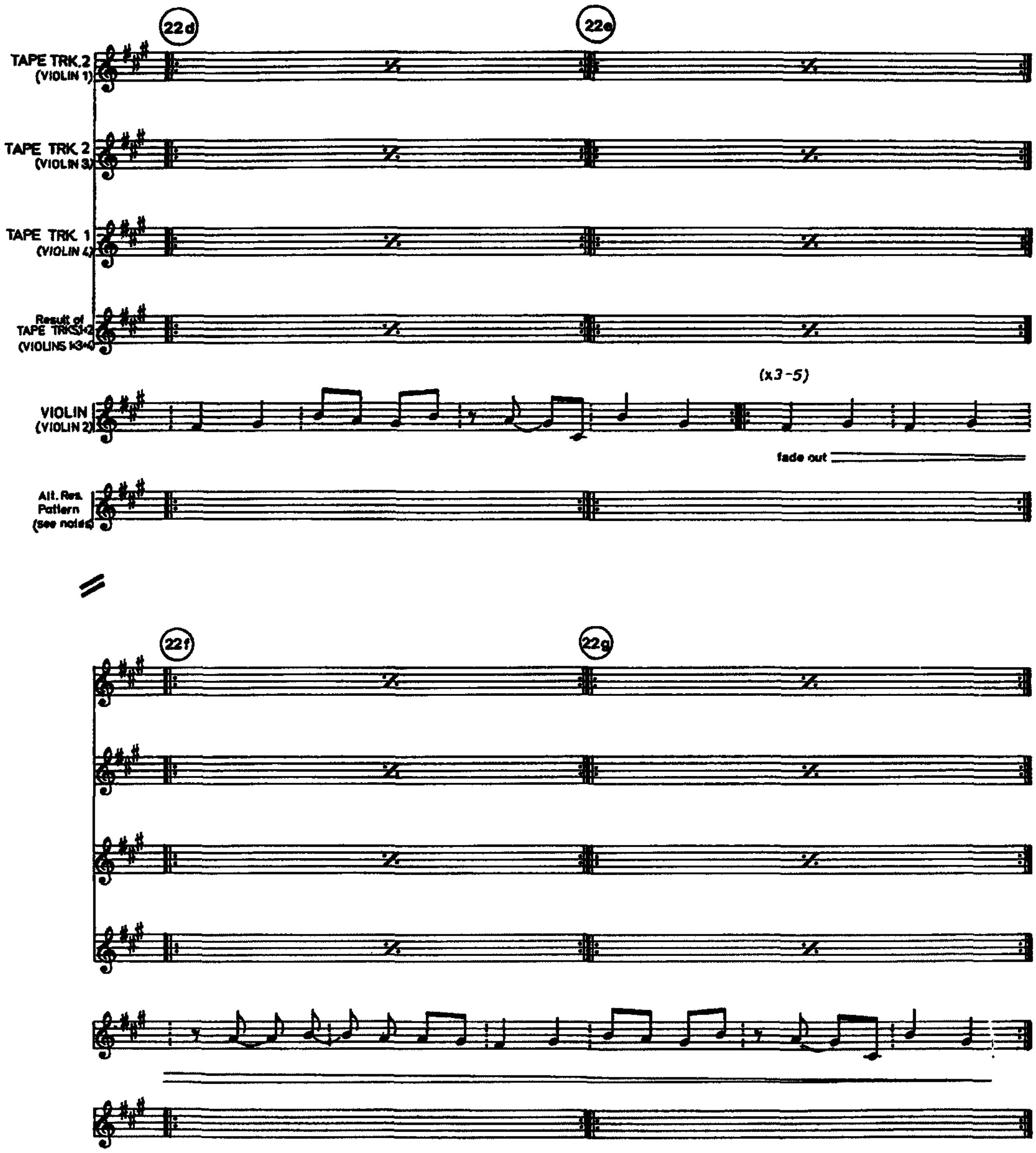


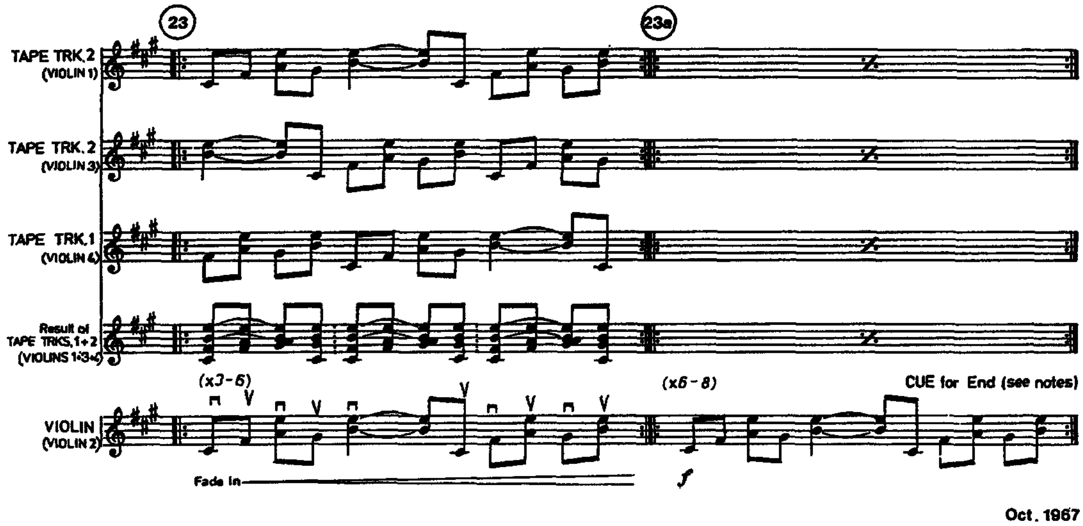
20b
20c
hold tempo 1
hold tempo 1
hold tempo 1
hold tempo 1
hold tempo 1
hold tempo 1
tempo 1
tempo 1
(x2-4)
(x2-4)
(x2-4)
(x2-4)
hold tempo 1
accel v. slightly
hold tempo 1
accel. v. slightly
hold tempo 1
accel. v. slightly
hold tempo 1
accel. v. slightly
20d
21
APE TRK. 2 (VIOLIN 1)
APE TRK. 2 (VIOLIN 3)
APE TRK. 1 (VIOLIN 4)
Result of APE TRKS. 1+2 IOLINS 1+3+4)
VIOLIN (VIOLIN 2)
Alt. Res. Pattern (see notes)
hold tempo 1
hold tempo 1
hold tempo 1
tempo 1
(x2-4)
(x3-6)
(x2-6)
hold tempo 1
Fade out
Fade in
f
accel. v. slightly
hold tempo 1
accel. v. slightly



21a
21b
TAPE TRACK 2
(VIOLIN 1)
hold tempo 1
hold tempo 1
TAPE TRACK 2
(VIOLIN 3)
hold tempo 1
hold tempo 1
TAPE TRACK 1
(VIOLIN 4)
hold tempo1
hold tempo1
Result of
TAPE TRKS.1+2
(VIOLINS 1+3+4)
tempo 1
tempo 1
(x3-6)
(x2-6)
(x3-6)
(x2-6)
VIOLIN
(VIOLIN 2)
hold tempo 1
accel. v. slightly
hold tempo 1
accel. v. slightly
Alt.Res.
Pattern
(see notes)
hold tempo 1
accel v slightly
hold tempo 1
accel v. slightly
21c
21d
hold tempo 1
hold tempo 1
hold tempo1
tempo 1
(x3-6)
(x2-6)
(x3-6)
hold tempo 1
accel. v. slightly
hold tempo 1
Fade out
hold tempo 1
accel v slightly
hold tempo 1


22
22a
TAPE TRK. 2 (VIOLIN 1)
TAPE TRK. 2 (VIOLIN 3)
TAPE TRK. 1 (VIOLIN 4)
Result of TAPE TRKS.1+2 (VIOLINS 1-3-4)
VIOLIN (VIOLIN 2)
(x3-5)
Fade in
Alt. Res. Pattern (see notes)
22b
22c
(x3-5)
f


22d
22e
TAPE TRK. 2 (VIOLIN 1)
TAPE TRK. 2 (VIOLIN 3)
TAPE TRK. 1 (VIOLIN 4)
Result of TAPE TRKS 1+2 (VIOLINS 1-3-4)
(x3-5)
VIOLIN (VIOLIN 2)
fade out
Alt. Res. Pattern (see notes)
22f
22g


23
23a
TAPE TRK. 2 (VIOLIN 1)
TAPE TRK. 2 (VIOLIN 3)
TAPE TRK. 1 (VIOLIN 4)
Result of TAPE TRKS. 1+2 (VIOLINS 1+3+4)
(x3-6)
(x6-8)
CUE for End (see notes)
VIOLIN (VIOLIN 2)
Fade in
Oct. 1967

Appendix C: Pilot Study

This appendix contains the pilot study which was conducted in preparation for Experiments 1A and 1B reported in Chapter 5.

Pilot Study: Testing the Suitability of the Space-Bar

Aim

In both Experiments 1A and 1B, reported in Chapter 5, subjects used the space-bar of the computer keyboard to tap the underlying beat of a series of patterns from Reich's *Piano* Phase. The aim of the Pilot Study reported here was to refine techniques to be used in the main experiments. Specifically, the Pilot Study helped to assess the device for registering subject responses. In this way, the study was designed to rule out the possibility that the position of taps on the space-bar (where the subjects struck the key) would effect the accuracy of recording taps.

Method

Stimuli

Stimuli consisted of isochronous sequences presented at five different rates. The presentation rates (139 ms, 150 ms, 200 ms, 250 ms, 300 ms), and the piano sound (from a Kurtzweil 2000), chosen for the experiment were identical to those used in Experiment 1A. Sequences were presented at the same volume for all subjects, and the silent interval between tones was set at 50 ms. That is, the duration of tones were 89 ms, 100 ms, 150 ms, 200 ms, and 250 ms respectively. The sequences were all 144 tones in length, so that deviations could be calculated over the period of time subjects would be responding (tapping) in the main experiment (Experiment 1A). The sequences were created on a Macintosh computer using Max 3.5. Descriptions of the software are provided in the methodology section of Experiment 1A. A copy of the program designed specifically for this pilot is provided in Appendix F. Subjects listened to the sequences through high quality headphones.

Subjects

Four subjects, aged 21, 26, 35 and 54, took part in the study. Two of the subjects were musicians with over 10 years playing experience, and two were non-musicians. All subjects were computer literate.

Procedure

Participants were tested one at a time, during sessions which took approximately 10 minutes to complete. The researcher explained the opening display screen of the computer to participants, and they were asked to follow the instructions on the screen throughout the pilot.

The experimental procedure consisted of two parts, using a different computer key in each part to respond to identical stimuli. In one half of the pilot, subjects used the space-bar to register responses. In the other half, subjects used the zero key on the number pad of the keyboard. Two of the subjects began using the space-bar, while the remaining two subjects began using the zero key.

Subjects clicked a button with the mouse to begin each sequence. They were asked to tap the space-bar, or zero key, of the computer keyboard in time with the underlying beat of the sequence in each trial. The instruction was to begin tapping as soon as a regular pulse was identified, and to continue tapping until the sequence stopped.

In each half of the pilot, trials were presented in random order. There was a two minute break between the completion of the first five trials, and the beginning of the second half of the experiment, which tested the alternative key on the computer keyboard. The researcher sat outside the studio, and was available for help if required.

Results and Discussion

In synchrony with the start of the sequence, the time of each tap was recorded, in milliseconds, by the software's clocking device. This data was used to measure the distance between subject taps and the actual tones of the sequences. Table A1 shows the mean and standard deviations for the space-bar and the zero key for all presentation rates. In addition, the minimum and maximum time in milliseconds that subjects strayed from the beat in each trial are provided. The results for the space-bar are shown in bold.

Table A1 Results of Pilot Study

Mean and standard deviation of duration (in milliseconds) that subjects deviated from tones for each of the five presentation rates; and minimum and maximum distances which occurred between subject taps and the sound events in each trial. Negative values indicate that subjects tapped before the beat. Results for the space-bar are presented in bold.

a. 139 ms

Subject No.	Mean		SD		Minimum		Maximum	
1	**30.17**	61.75	**23.28**	22.04	**-5**	15	**115**	195
2	**28.70**	33.41	**9.46**	11.93	**6**	11	**48**	59
3	**30.73**	36.85	**13.54**	15.27	**-22**	-13	**61**	40
4	**44.39**	33.46	**11.92**	17.80	**12**	-4	**74**	70
Total Mean	**133.99**	165.47						

b. 150 ms

Subject No.	Mean		SD		Minimum		Maximum	
1	**45.36**	73.19	**15.70**	31.74	**0**	10	**115**	135
2	**41.47**	36.03	**14.38**	10.42	**15**	20	**75**	60
3	**4.63**	29.63	**20.95**	18.55	**-50**	-20	**60**	70
4	**41.71**	45.15	**15.38**	15.48	**15**	5	**75**	80
Total Mean	**133.17**	184						

c. 200 ms

Subject No.	Mean		SD		Minimum		Maximum	
1	**26.54**	37.81	**13.27**	26.15	**-10**	0	**55**	105
2	**23.24**	36.10	**13.58**	17.34	**0**	-10	**45**	85
3	**12.42**	42.31	**13.50**	14.29	**-20**	5	**40**	80
4	**28.49**	32.17	**16.06**	22.19	**-5**	-60	**215**	40
Total Mean	**90.69**	196.10						

d. 250 ms

Subject No.	Mean		SD		Minimum		Maximum	
1	**32.32**	16.43	**14.03**	17.59	**-10**	0	**55**	105
2	**22.93**	19.08	**12.32**	11.64	**-25**	-10	**55**	55
3	**19.78**	19.10	**17.07**	11.89	**-15**	-20	**75**	40
4	**32.24**	41.66	**17.11**	12.14	**15**	-5	**145**	185
Total Mean	**107.27**	96.27						

e. 300 ms

Subject No.	Mean		SD		Min		Max	
1	**18.39**	34.14	**15.43**	12.68	**-25**	0	**80**	65
2	**25.59**	22.07	**14.31**	13.39	**0**	-5	**65**	155
3	**13.84**	14.42	**15.84**	15.77	**-30**	-40	**50**	35
4	**33.43**	34.42	**17.82**	18.34	**5**	0	**80**	75
Total Mean	**91.25**	105.05						

With the exception of 250 ms, the total means suggest that subjects deviated less from the sound events when using the space-bar to tap the underlying beat of the sequences, than for taps on the zero key.

Wing (1973) (cited in Parncutt, 1994), explains the hesitation common to periodic tapping as a motor delay between the intended response and the actual response. Other studies (such as Fraisse, 1980, 1987), have found that listeners anticipated events when tapping pulse responses (Parncutt, 1994, p. 419). In this study, the results indicate the tendency for subjects to tap slightly after the beat (in accord with Wing, 1973), rather than to anticipate the upcoming beat. As indicated by the minimum values in Table 5-1, however, some subjects tapped prior to the sound events, the widest margin over all trials being 50 ms.

The aim of this pilot was to test the suitability of the space-bar as a device for registering pulse responses. Results suggest that the accuracy of recording subjects responses was not compromised by the position of taps on the space-bar, that is, where the subjects struck the key. In addition to the size and position of the space-bar on the computer keyboard, this finding reinforced the suitability of the space-bar as a device for registering subjects responses in Experiments 1A and 1B.

Appendix D: Questionnaire

The questionnaire presented in this appendix was administered to all subjects who participated in Experiments 1 and 2 to collect information regarding subjects' musical background and experience, attitude toward music and musical ability. The closing questionnaires (section D), also included here, were different for Experiments 1 and 2, collecting information specific to the experimental task.

Questionnaire for Experiments 1 and 2

Experiment [ ]

Subject Code [ ]

Date [ ]

Subjects name (please print) ____________________
Contact phone number ____________________
Date of Birth ____________________

Questionnaire

This questionnaire is for research purposes only

A: Musical background and experience

Please answer questions 1-8 below as accurately as possible

1. Have you ever played a musical instrument? Yes No

   If no, go to Question 5.

2. If yes, please indicate which instrument(s) you play, the number of years you have played, and whether you are still playing the instrument now.

Instrument	Number of years	Still playing (Yes or No)

3. With which of the instruments listed above have you received formal musical training,
   and for how many years?

Instrument Number of years

__________ ____
__________ ____
__________ ____

4. On average, how many hours (per week) do you presently spend playing the instrument(s) listed above? (Circle the appropriate answer)

1. None   2. 1-2 hours   3. 2-5 hours   4. 5-10 hours   5. more than 10 hours

5. Have you elected a music course at either secondary school or tertiary level?

1. Yes (secondary school)   2. Yes (tertiary level)   3. No

If no, go to question 7.

6. If yes (tertiary level), please indicate the type of course, and the number of years of study (including courses currently being undertaken)

Name of course or degree ________________________________
No. of years of study ________________________________

7. How would you describe your music listening skills? (Circle appropriate number)

1. Very underdeveloped, I rarely listen to music
2. Moderately developed, I like music but don't listen to it often
3. Somewhat developed, I like music and listen to it often
4. Highly developed, I listen to music a great deal
5. Very highly developed, I'm consumed by music and listen to it constantly

8. Please indicate how often you spend listening to each of the following styles of music by circling the appropriate numbers:

Style	Never	Rarely	Sometimes	Often	Constantly
jazz (including blues)	1	2	3	4	5
rap/funk/soul	1	2	3	4	5
trance/techno	1	2	3	4	5
rock/grunge/pop	1	2	3	4	5
country and western	1	2	3	4	5
instrumental music (eg. solo or orchestral)	1	2	3	4	5
vocal art (eg. opera)	1	2	3	4	5
ethnic music	1	2	3	4	5
easy listening/ new age	1	2	3	4	5
musicals/cabaret	1	2	3	4	5
contemporary (eg. avant garde, experimental, 12-tone)	1	2	3	4	5
other (please name) ------------------------------	1	2	3	4	5

Section B: Attitude toward music

Answer the next 9 questions using the 7 point scale. Circle the number that reflects your view as accurately as possible.

1. To what extent is music important to you?

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

2. To what extent do you enjoy listening to music?

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

3. How much time do you spend listening to 'classical' styles of music?

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

4. How much time do you spend listening to 'popular' styles of music?

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

5. How much time do you spend listening to other styles of music (eg. religious, ethnic, folk, jazz)

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

6. To what extent do you enjoy (or do you think you would enjoy) going to 'classical' music concerts?

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

7. To what extent do you enjoy (or do you think you would enjoy) going to 'popular music' concerts? (including large and small scale venues)

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

8. To what extent do you enjoy (or do you think you would enjoy) going to other types of music concerts? (eg. ethnic, folk, jazz)

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

9 To what extent would you like to spend your money on sound equipment, records, tapes and discs?

1	2	3	4	5	6	7
Not at all	Very little	A small amount	A fair amount	Quite a bit	A lot	A great deal

Section C: Musical ability

The remaining questions relate to your perception of your musical ability

How would you rate your ability to:

9. play a musical instrument?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

10. read music?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

12. compose music?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

13. improvise?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

14. sing in tune?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

15. How would you rate your overall vocal ability?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

16. keep in time when singing or playing? (maintain a steady rhythm)

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

17. play percussion instruments? (eg. tuned and untuned)

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

18. listen with understanding to a range of musical styles? (eg. recognise elements like harmonic progressions, motivic development and other formal features)

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

19. listen with understanding to 'popular' musical styles?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

20. listen with understanding to 'classical' musical styles?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

21. listen with understanding to ‘ethnic’ musical styles?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

23. How would you rate your overall musical ability?

1	2	3	4	5	6	7
Very low	Quite low	A little below average	Average	A little above average	Quite high	Very high

<u>Section D: Closing questionnaire for Experiments 1A and 1B</u>

1. Did you have any difficulty following the instructions during the experiment?

   Yes No

   If yes, please comment in the space provided below

___

___

___

2. How would you rate the difficulty of the tapping task?

1.	2.	3.	4.	5.	6.	7.
Extremely easy	Somewhat easy	Moderately easy	Moderately difficult	Very difficult	Extremely difficult	Impossibly difficult

3. Are you familiar with the musical excerpts presented in the experiment?

1.	2.	3.	4.	5.	6.	7.
Didn’t recognise the music at all	Not sure if I’ve heard it before	Have heard it once or twice	Know it reasonably well	Know it quite well	Know it very well	Know it extremely well and have studied it in depth

4. Did you ever change your mind (and consequently change your response) during the course of a musical sequence ?

1.	2.	3.	4.	5.
Never	Very rarely	Sometimes	Often	Constantly

5. On average, how long did it take you to identify a pulse once the sequence had started?

1.	2.	3.	4.
Found a pulse instantly	Took a couple of seconds to find a pulse	Took more than a few seconds	Took quite some time

6. Overall, how consistent was your response time in identifying a pulse?

1.	2.	3.
Consistently quick for each trial	Varied for each trial	Consistently slow for each trial

7. Did you find that the length of the experiment made it difficult to maintain concentration?

   Yes No

   If yes, describe how it effected your performance.

____

____

____

8. Please use the space below to comment on any other aspect of the experiment not covered in the questions above (eg. equipment, sound quality, distractions, inconsistencies etc.)

____

____

____

____

____

Researchers Use Only

Load Order [ ]

Time [ ]

Category [ ]

Section D: Closing questionnaire for Experiments 2A and 2B

1. Did you have any difficulty following the instructions during the experiment?

   Yes No

   If yes, please comment in the space provided below

   ____

   ____

   ____

2. How would you rate the difficulty of the task?

1.	2.	3.	4.	5.	6.	7.
Extremely easy	Somewhat easy	Moderately easy	Moderately difficult	Very difficult	Extremely difficult	Impossibly difficult

3. Did you find the rating scale difficult to use?

   Yes No

   If yes, please explain why

   ____

   ____

   ____

4. Are you familiar with the musical excerpts presented in the experiment?

1.	2.	3.	4.	5.	6.	7.
Didn't recognise the music at all	Not sure if I've heard it before	Have heard it once or twice	Know it reasonably well	Know it quite well	Know it very well	Know it extremely well and have at studied it in depth

5. Did you ever change your mind (and consequently change your response) when using the rating scale?

1.	2.	3.	4.	5.
Never	Very rarely	Sometimes	Often	Constantly

6. Did you find that the length of the experiment made it difficult to maintain concentration?

Yes No

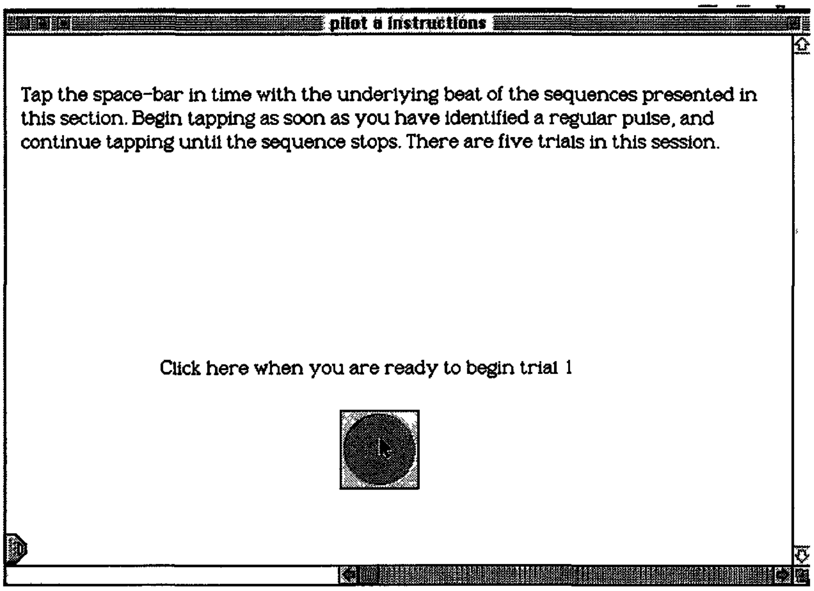
If yes, describe how it effected your performance.

7. Please use the space below to comment on any other aspect of the experiment not covered in the questions above (eg. equipment, sound quality, distractions, inconsistencies etc.)

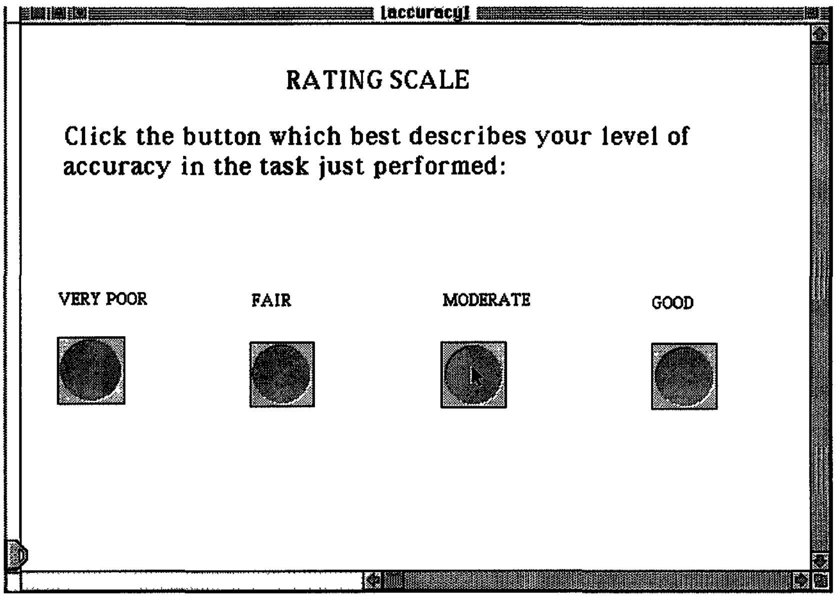
Appendix E: Displays used in Pilot Studies, Experiment 1A, 1B, 2A and 2B

This appendix consists of screen dumps of the opening displays and response screens for each of the experiments reported in the thesis (Pilot Studies, Experiments 1A and 1B and Experiments 2A and 2B). Additional components of the program are shown in Appendix E, F, and G; that is, the programs controlling the experimental stimuli, the order of sequence presentation and examples of data compilers respectively. Each of the opening displays with text instructions were explained to the participant by the researcher prior to the experiment (see Chapters 5 and 6). The instructions on the screen were kept as clear and concise as possible, to make reading and concentration relatively easy.

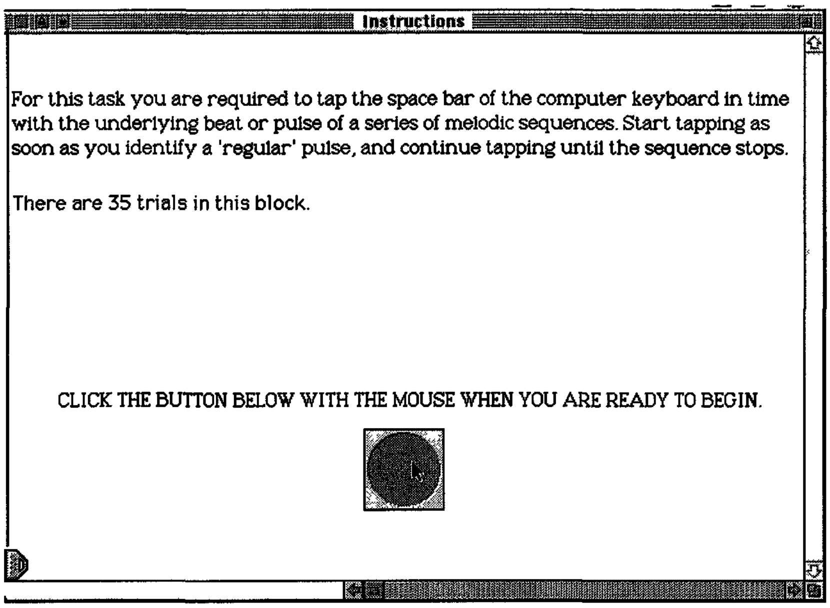
Opening Display for Pilot Studies



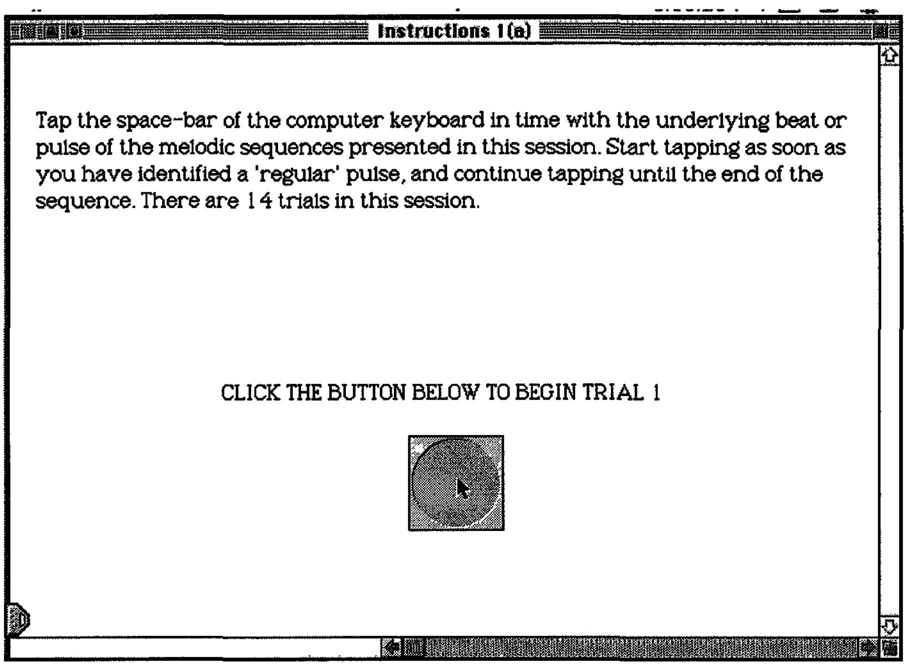
Rating Scale Display for Pilot Study: Accuracy of Subject's Taps



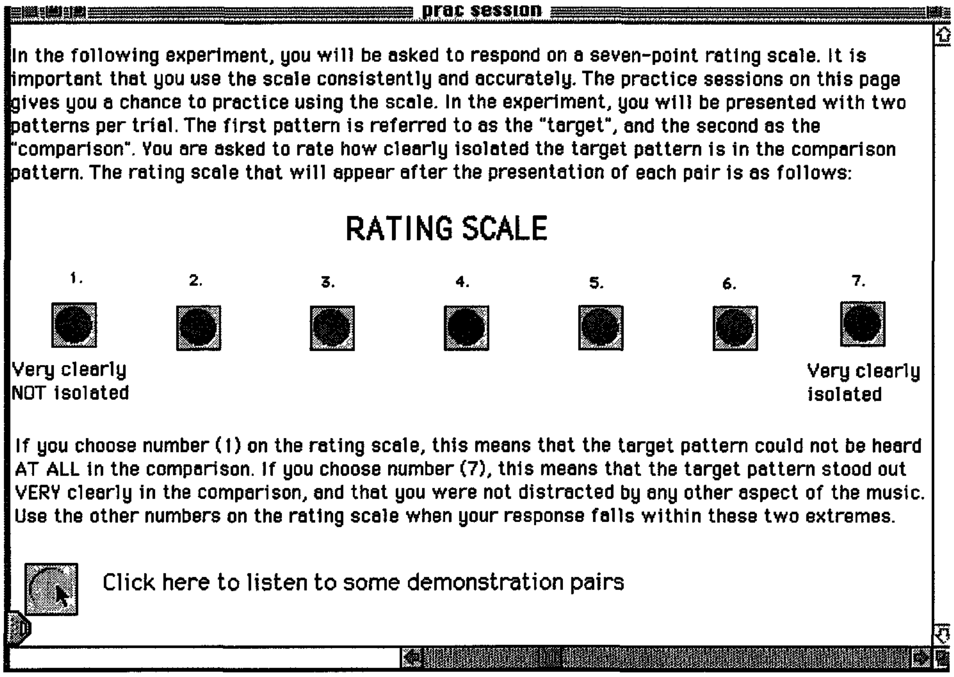
Opening Display for Experiment 1A



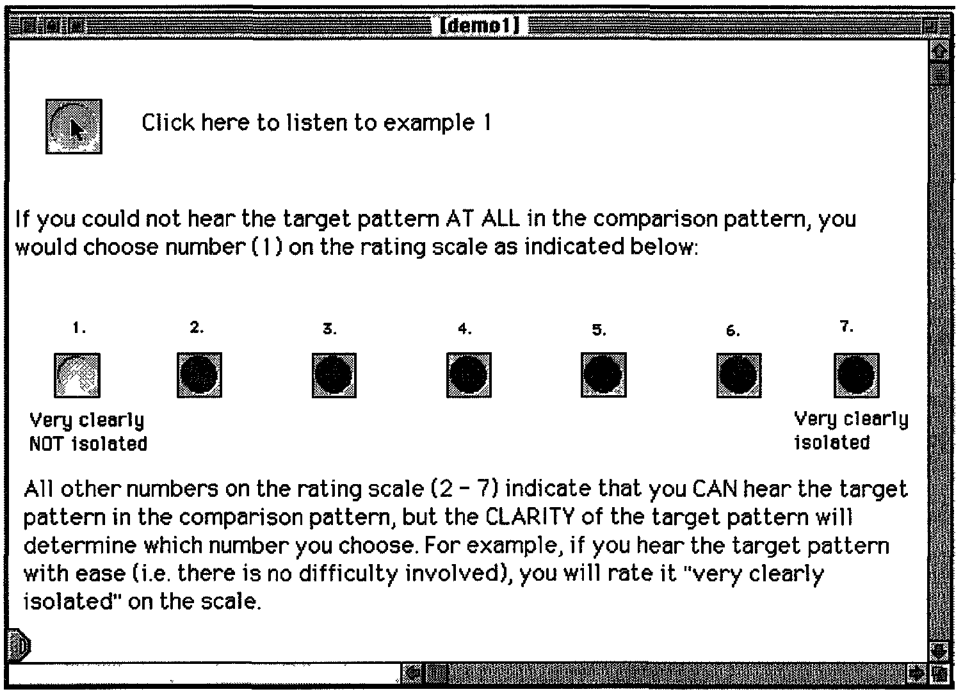
Opening Display for Experiment 1B



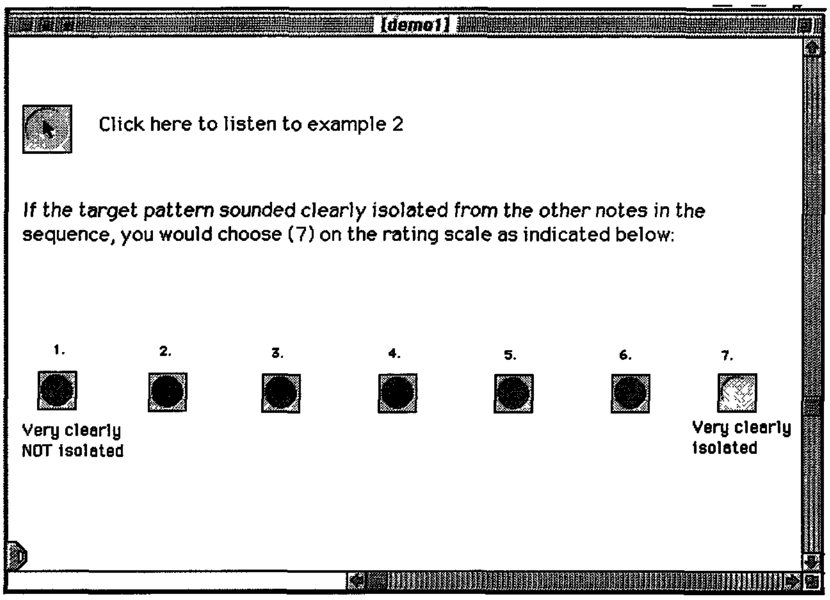
Practice Session Instructions Screen for Experiment 2A



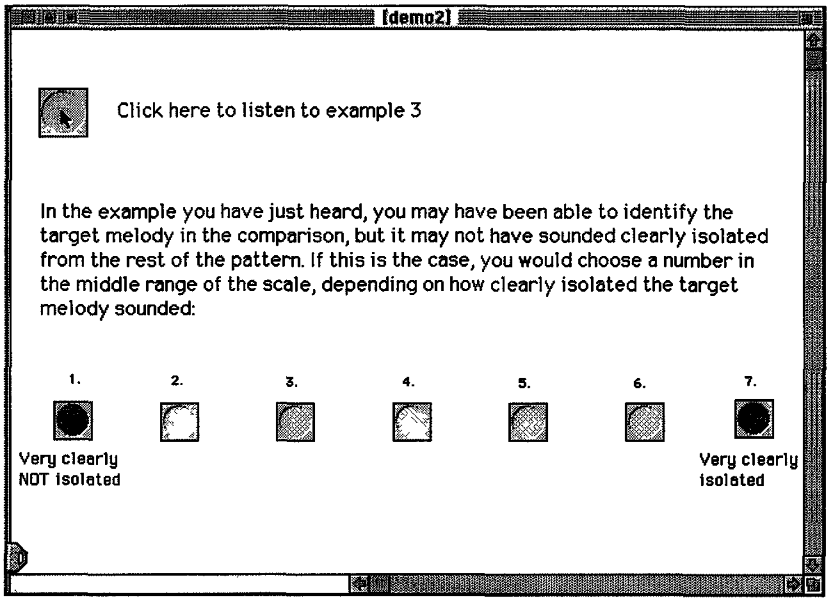
Practice Session for Experiment 2A (Demonstration 1)



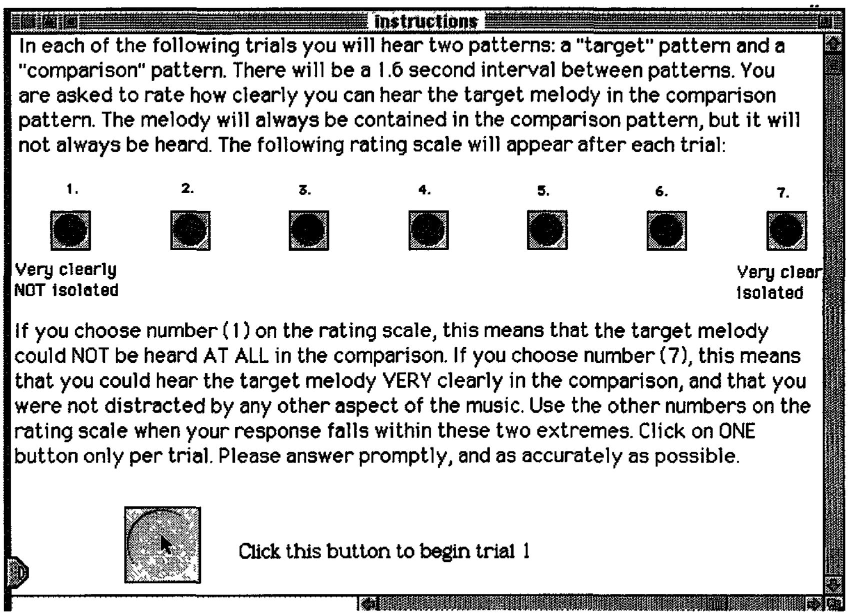
Practice Session for Experiment 2A (Demonstration 2)



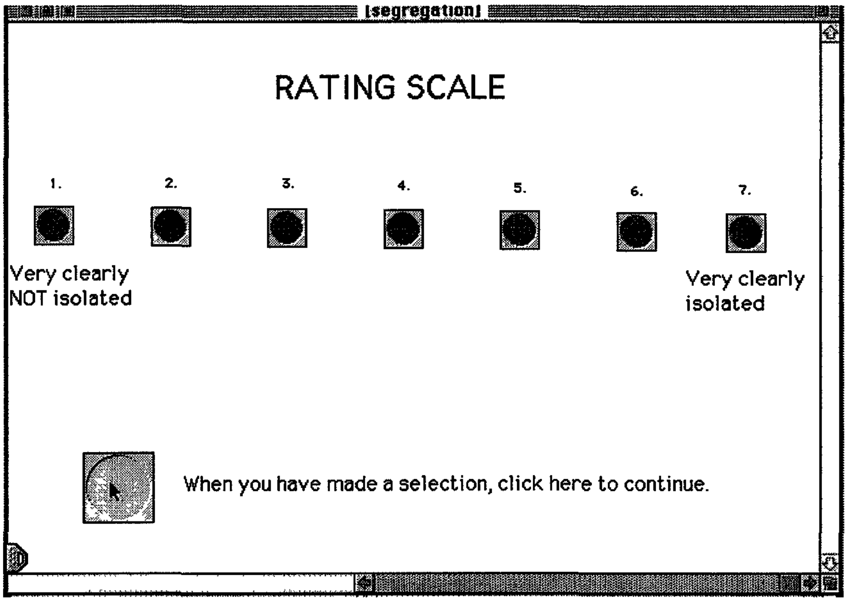
Practice Session for Experiment 2A (Demonstration 3)



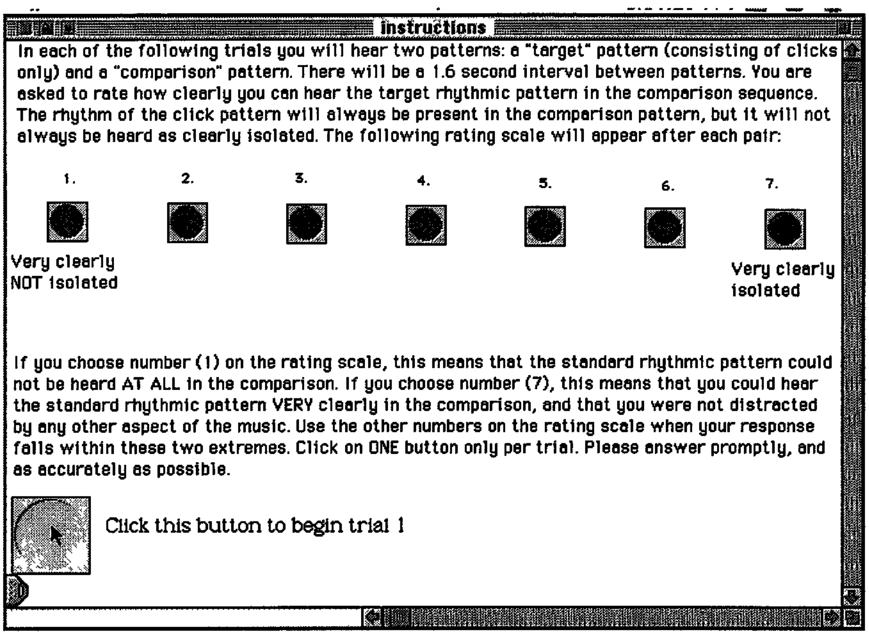
Opening Display for Experiment 2A



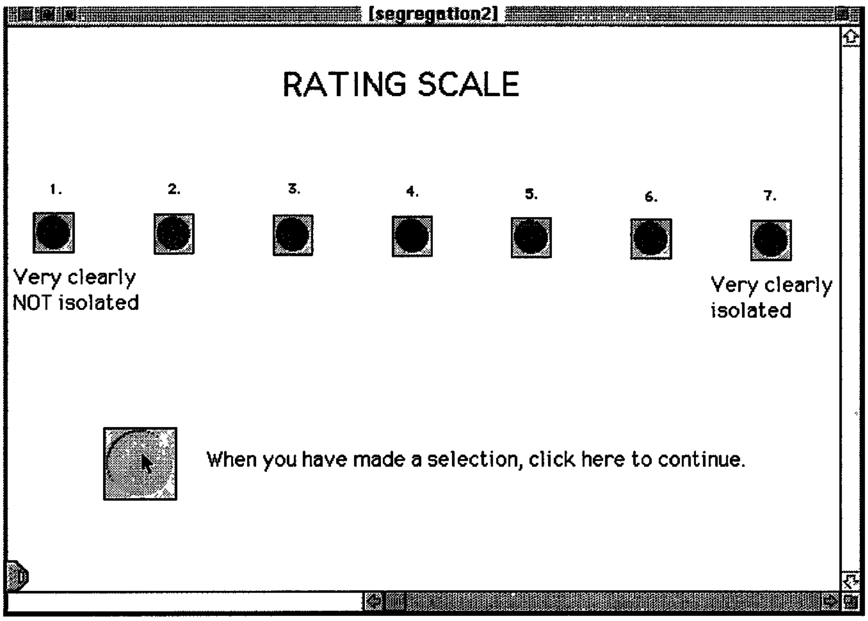
Rating Scale for Experiment 2A



Opening Display for Experiment 2B



Rating Scale for Experiment 2B



Appendix F: Programs Controlling Experimental Stimuli

Appendix F provides examples of the programs which were designed to create, and control the timing of, experimental stimuli. *Max* is a high level graphical programming language. Programs are developed using graphical *objects* rather than text lines. The inputs and outputs of objects are connected via patch cords. The numbers which appear in boxes with a single border denote specific pitches (for example, 64 = E4). The examples provided below are samples only, and have been isolated from larger programs so that specific features can be observed. A glossary of programming objects is provided below, to demonstrate their function within the examples provided.

Glossary of Relevant Objects
Source: Adapted from Max References (manual), Opcode Systems (1995).

button  Flashes on any message and sends a bang. Buttons attached to rating scale messages send the response to a dialog box, which is saved in a data file.

capture Stores numbers to view or edit.

clocker Reports elapsed time at regular intervals.

coll Stores and edits a collection of different messages.

counterCounts the bangs received, and outputs the count.

delay Delays a bang before passing it through the outlet.

key Reports keys types (tapped) on the Macintosh keyboard.

loadbang Sends a bang automatically when the patch is loaded.

makenote Generates a note-off message following each note-on.

metro Outputs a bang at regular intervals. The first argument sets an initial value for the time interval at which metro sends its output.

notein Outputs incoming MIDI note messages. A number next to the notein object specifies a channel number.

noteoutTransmits MIDI note messages.

pack Combines numbers and symbols into a list.

patcher Creates a subpatch within a patch.

pcontrol Opens and closes subwindows within a patcher.

print Prints any message in the Max window (dialog box)

random Generates a random number between 0 and one less than its maximum limit.

receive (r) Receives messages without patch cords from send objects (see below).

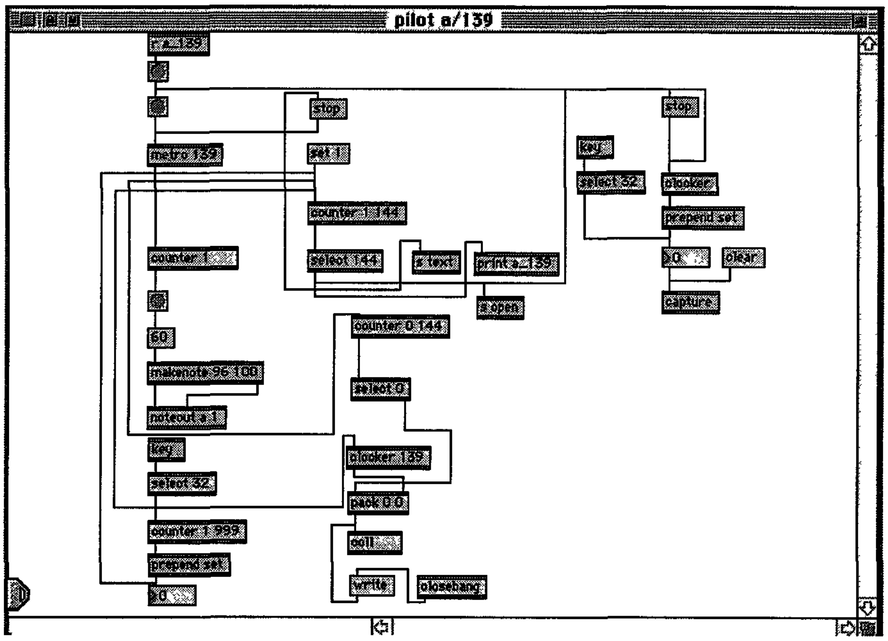
send (s) Sends messages without patch cords to receive objects.

select (sel) Selects certain inputs and passes the rest on.

set	Resets the counter.
stop	Stops the counter.
tempo	Outputs numbers at a metronomic tempo.
urn	Generates random numbers without duplicates.

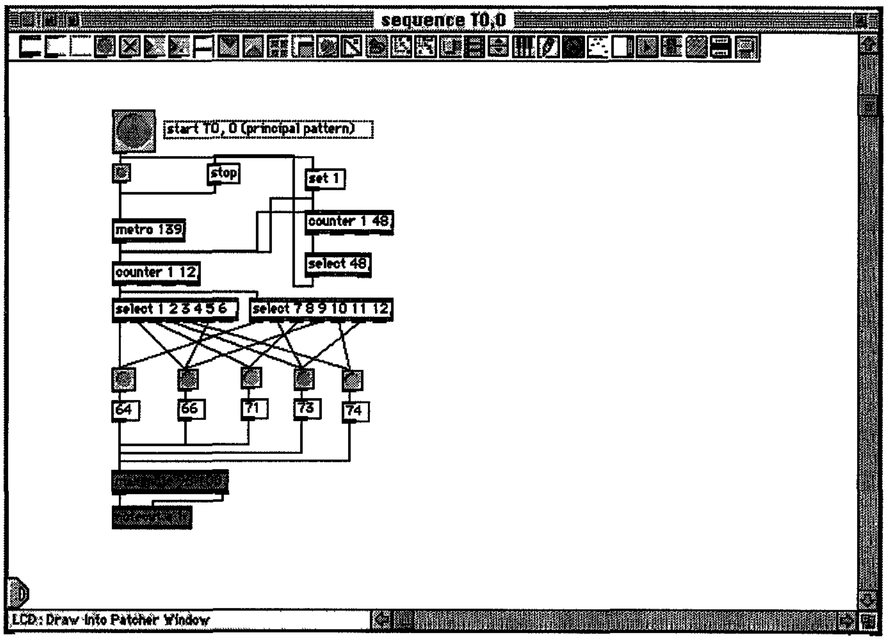
Programs Controlling Stimuli for Pilot Studies

A linked patch controlling the order of trials sends a message which is received by the stimulus program shown below, which initiates the onset of the sequence. This program records subject's taps on the space-bar of the computer keyboard (see key: select 32). The metro object is set to 139ms.



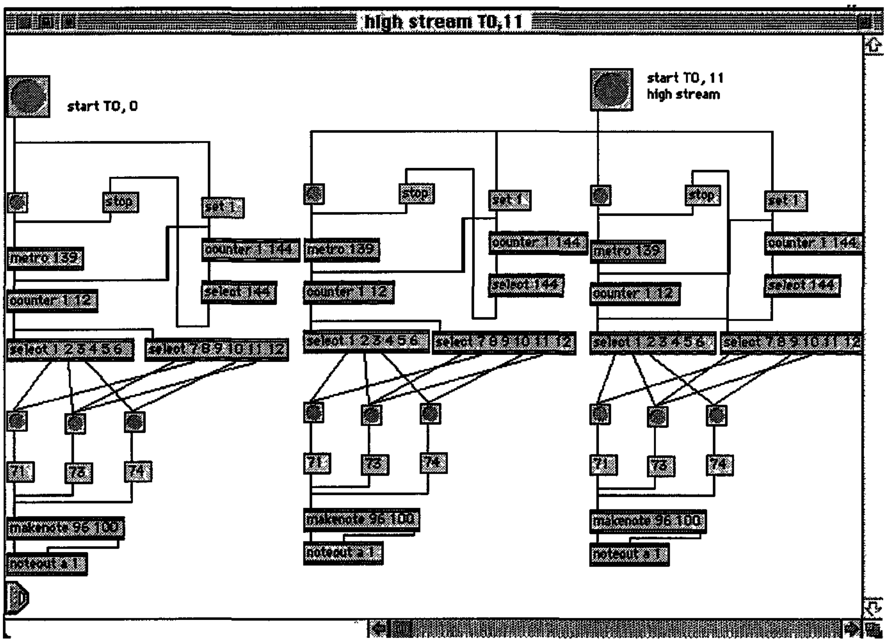
Programs Controlling Stimuli for Experiment 1A

The program below controls the onset of the principal pattern of *Piano Phase* (T0,0).



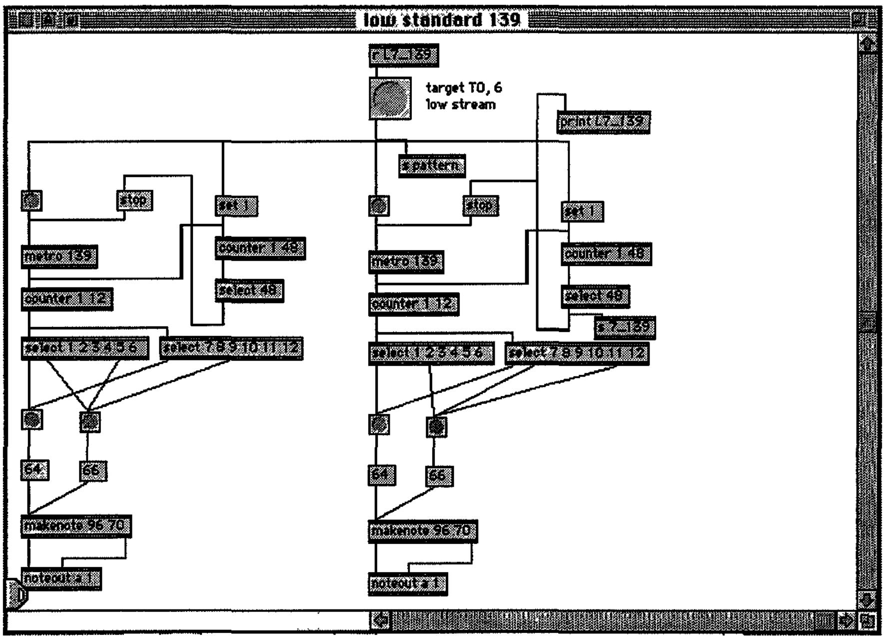
Programs Controlling Stimuli for Experiment 1B

This example shows the programs controlling both the low pattern in its original order (T0,0), and the low pattern for T0,11. As demonstrated, T0,11 consists of the original sequence and a duplication of it, which shifts the rhythmic transposition by one degree.



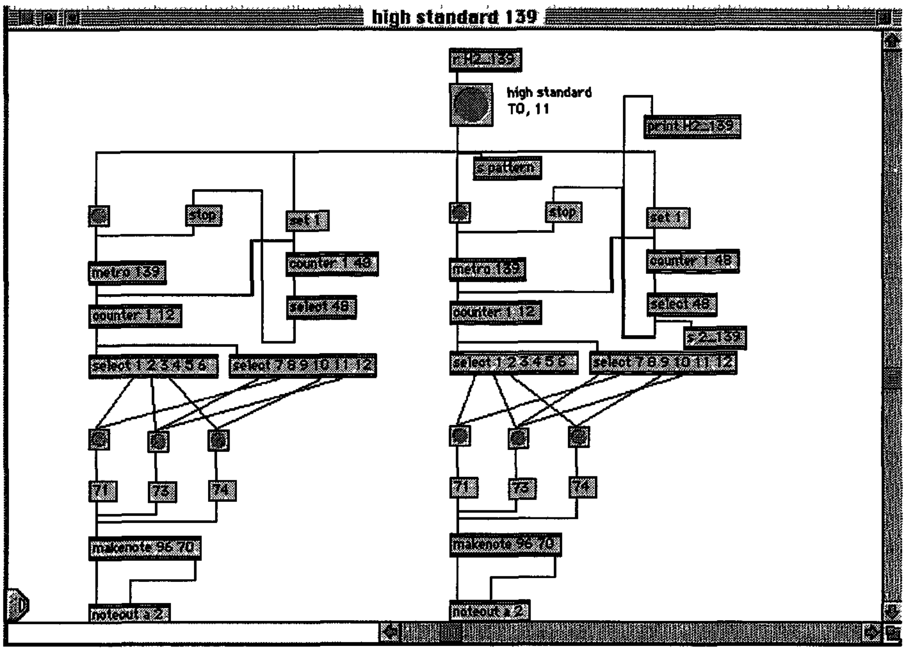
Programs Controlling Stimuli for Experiment 2A

This example shows the program controlling the low target pattern in T0,6, which is proceeded by the composite pattern T0,6 after a 1.6 second silence.



Programs Controlling Stimuli for Experiment 2B

This example shows the program controlling the high target pattern in Experiment 2B, presented as a series of "clicks". This sequence sends a message to the comparison pattern, which is initiated after a 1.6 second silence.

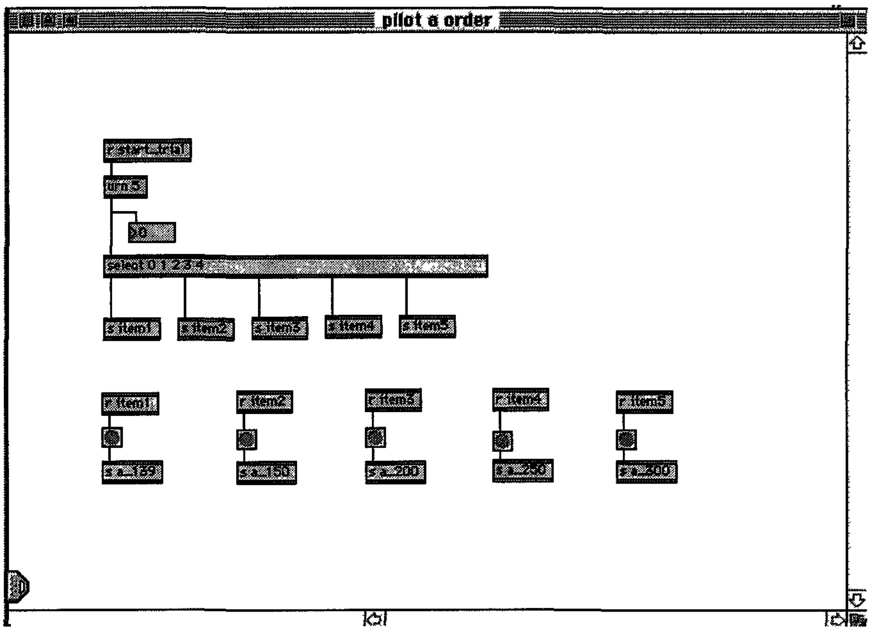


Appendix G: Order of Trials in Pilot Studies, Experiments 1A and 1B, and Experiments 2A and 2B

Appendix G includes the computer programs which were designed to control the order of trials in each experiment. For both Pilot Studies, the order of sequence presentation was randomly selected by the program for each subject when the program was initiated. In Experiment 1A, trials were presented in one of three orders (42 trials). These orders were constructed to avoid consecutive sequences containing either the same tempo or the same pattern. This was implemented to avoid metric carry over effects. In Experiment 1B, the order of trial presentation was different for each subject. In Experiments 2A and 2B, target and comparison pairs were presented to subjects in one of three orders.

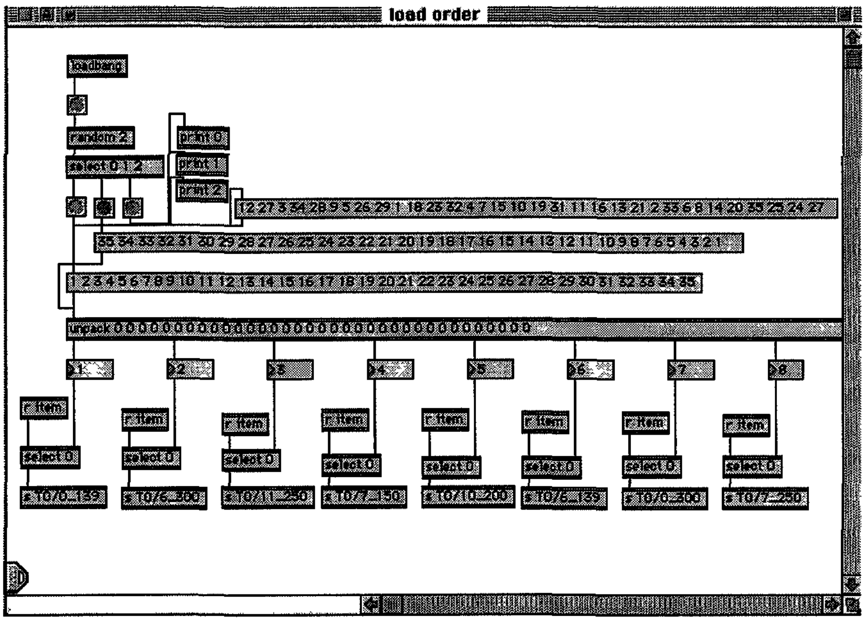
Order of Trials for Pilot Studies

Selects the order of trials randomly, and sends a message to a stimulus patch which initiates the sequence.



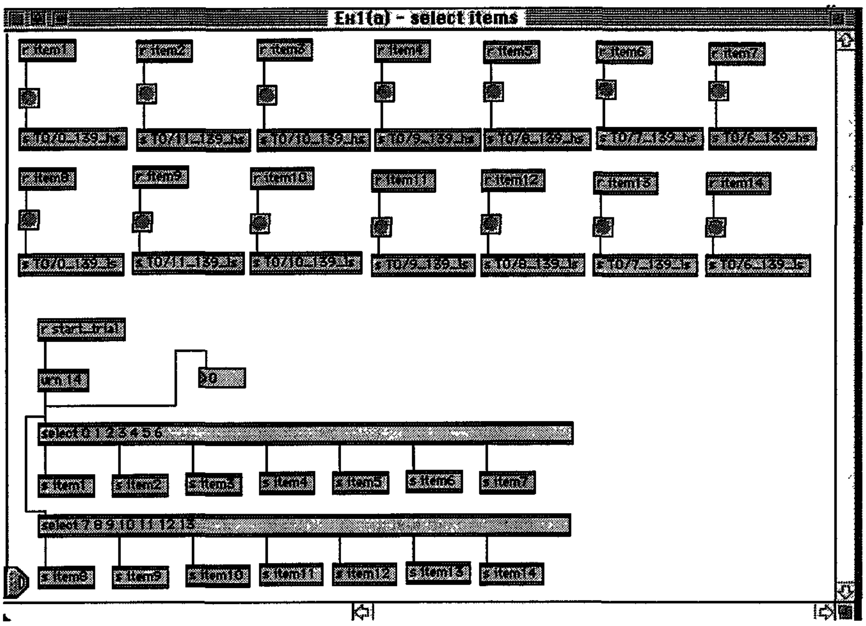
Order of Trials for Experiment 1A

Selects one of three orders (specified in the narrow horizontal bands). Each number is connected to a particular sequence in the experiment.



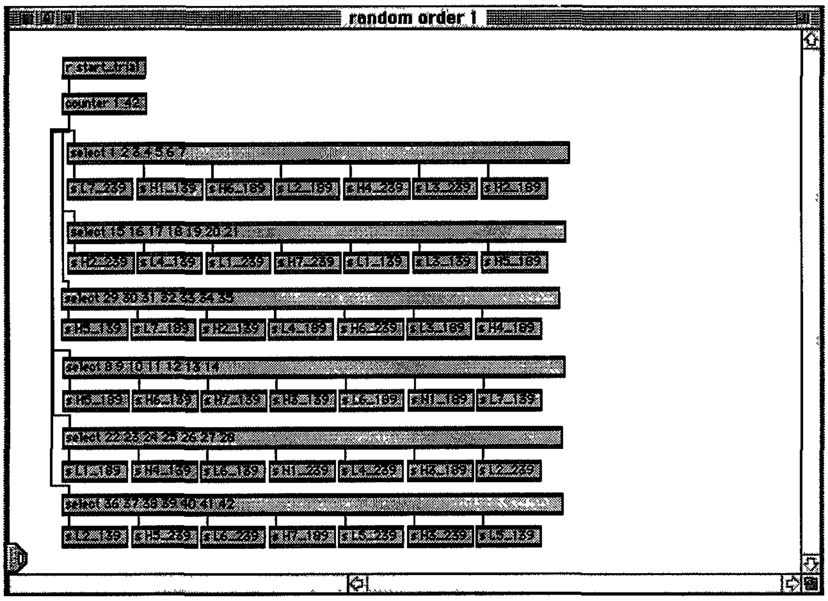
Order of Trials for Experiment 1B

Selects the order of the 14 sequences in the experiment randomly, without repeating any numbers.



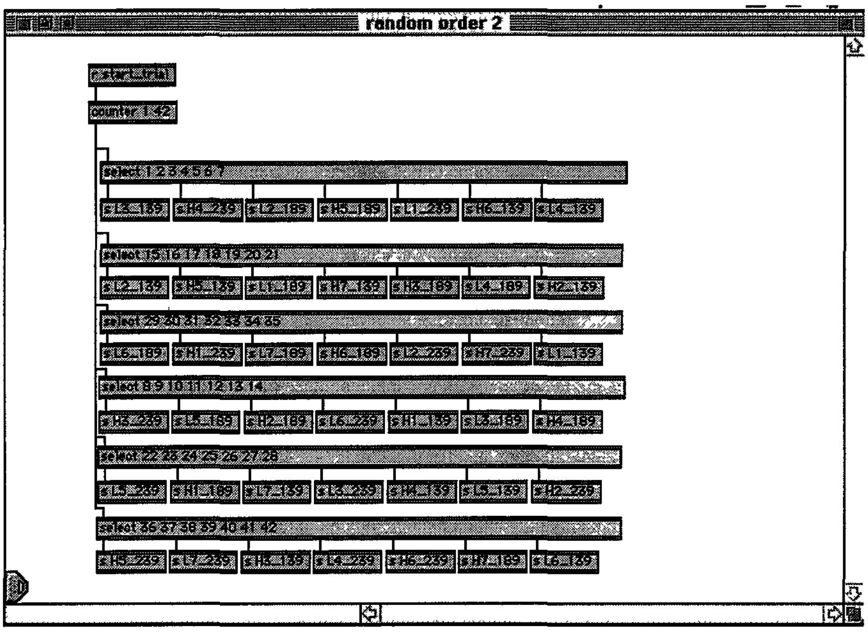
Order of Trials for Experiments 2A and 2B (example 1)

One of three possible orders for the presentation of sequences in Experiments 2A and 2B. Each number is associated with either a high stream or a low stream target pattern, which then initiates the onset of the comparison pattern.



Order of Trials for Experiments 2A and 2B (example 2)

One of three possible orders for the presentation of sequences in Experiments 2A and 2B. Each number is associated with either a high stream or a low stream target pattern, which then initiates the onset of the comparison pattern.



Appendix H: Data Compilers

This Appendix shows the format, and method of recording data for each of the experiments. In the Pilot Studies, and Experiments 1A and 1B, data was collected in two forms:

1. a clock recorded the time (in milliseconds) of each tap from the start of the sequence with 5 ms accuracy; and
2. a counter recorded which beats corresponded with a tap (indicated by a zero), and the time elapsed between taps.

Where the order of trials was selected randomly by the computer programming object “urn”, the name of the trial associated with the response was printed in a hidden dialog box.

Data Compiler for Pilot Studies (capture)

Responses were collected in a data file which indicated when the subject began tapping, and the actual time in milliseconds from the start of the sequence (synchronised with the clocking device). The zero immediately prior to the first number in the list denotes the first tap. The numbers collected for each subject were transported into Excel, so that the distance between each tap and the corresponding sound event could be measured.

```
KEY48_CAPT_139_PILOT
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2285
2875 3375 3915 4490 5030 5575 6160 6735 7260 7830 8360 8945 9490 10040
10595 11145 11710 12285 12830 13385 13925 14520 15085 15640 16215 16775
17310 17905 18495 19080 19655 19875
```

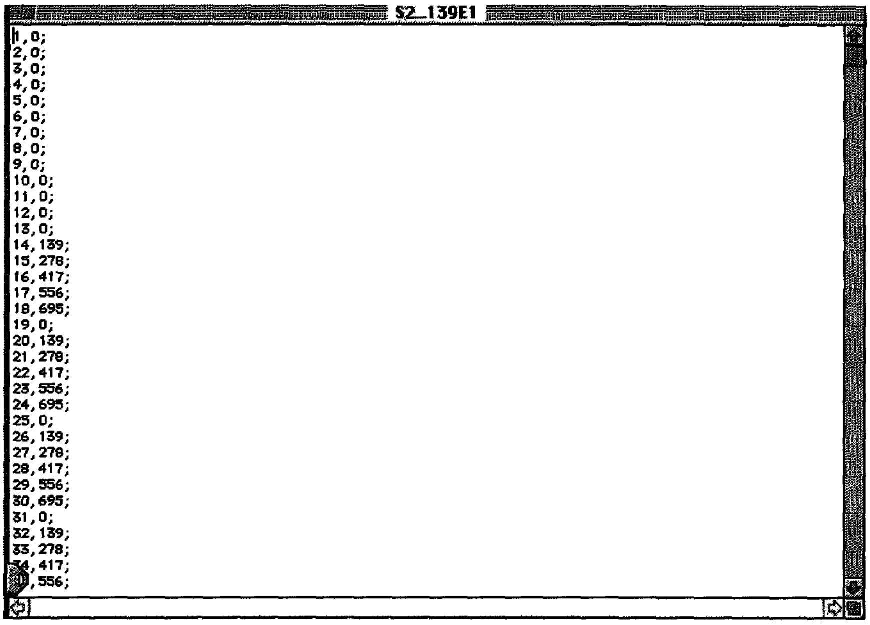
Data Compiler for Pilot Studies (collect)

The example below indicates that the subject began tapping on the 7th beat of the cycle, and tapped in groups of 6 for the remainder of the sequence (taps indicated with a zero).

```
EXP 1A_COLL_150_PILOT
1,0;
2,0;
3,0;
4,0;
5,0;
6,0;
7,0;
8,150;
9,300;
10,450;
11,600;
12,750;
13,0;
14,150;
15,300;
16,450;
17,600;
18,750;
19,0;
20,150;
21,300;
22,450;
23,600;
24,750;
25,0;
26,150;
27,300;
28,450;
29,600;
30,750;
31,0;
32,150;
33,300;
450;
```

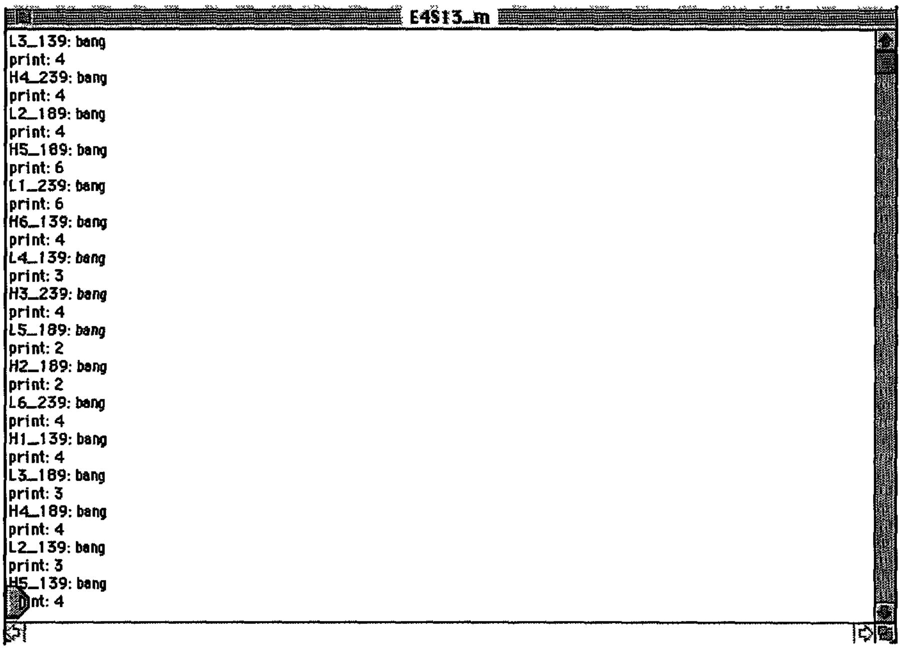
Data Compiler for and Experiments 1A and 1B

Once again, a zero was registered each time subjects tapped the space-bar of the computer keyboard. The remaining numbers indicate the time elapsed between taps in increments which accord with the tempo of the sequence (eg. metro = 139ms). These figures indicate the period (P) and phase (Q) of taps. The number of zeros prior to the count indicates which beat of the cycle (hence which sound event) the subject began tapping in synchrony with.


S2_139E1
1,0;
2,0;
3,0;
4,0;
5,0;
6,0;
7,0;
8,0;
9,0;
10,0;
11,0;
12,0;
13,0;
14,139;
15,278;
16,417;
17,556;
18,695;
19,0;
20,139;
21,278;
22,417;
23,556;
24,695;
25,0;
26,139;
27,278;
28,417;
29,556;
30,695;
31,0;
32,139;
33,278;
,417;
,556;

Data Compiler for Experiments 2A and 2B

Results show the name of each sequence (eg. L3_139), the order of sequence presentation, and the corresponding rating scale selection.


E4S13_m
L3_139: bang
print: 4
H4_239: bang
print: 4
L2_189: bang
print: 4
H5_189: bang
print: 6
L1_239: bang
print: 6
H6_139: bang
print: 4
L4_139: bang
print: 3
H3_239: bang
print: 4
L5_189: bang
print: 2
H2_189: bang
print: 2
L6_239: bang
print: 4
H1_139: bang
print: 4
L3_189: bang
print: 3
H4_189: bang
print: 4
L2_139: bang
print: 3
H5_139: bang
nt: 4